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SOCIETY OF MOTION PICTURE ENGINEERS

Membership in the Society of Motion Picture Engineers stands for unselfish service to the Industry. Applications for membership are by invitation and endorsement. All checks should be made payable to the Society of Motion Picture Engineers.

All receipts are expended directly to promote the objects of the Society and the interests of its members. There are no salaries or emoluments of any kind.

The following are extracts from the By-Laws:

The objects of the Society are: The advancement in the theory and practice of motion picture engineering and the allied arts and sciences, the standardization of the mechanisms and practices employed therein and the maintenance of a high professional standing among its members.

An Active Member is one who is actually engaged in designing, developing or manufacturing materials, mechanisms or processes used in this or allied arts, or who is interested directly in the art.

Any person of good character may be a member in any or all classes to which he is eligible.

Prospective members shall be proposed in writing by at least one member in good standing, and may be elected only by the unanimous vote of the Board of Governors.

All applications for membership or transfers in class shall be made on blank forms provided for the purpose, and shall be accompanied by the required fee.

The entrance fee for all members shall be twenty-five dollars ($25.00). The annual dues shall be ten dollars ($10.00), payable in advance before the annual meeting (October) of each year. That is, the total fee for the first year, which include the entrance fees and first annual dues, is $35.00 for all members.

PRESIDENT'S ADDRESS

The Society of Motion Picture Engineers has developed into an effective organization. It was less than three years ago when a handful of enthusiastic men at the suggestion of our past president, C. Francis Jenkins, met in Washington to discuss the advisability and possibility of forming a technical body in connection with the motion picture industry. This meeting, as you know, resulted in the formation of this Soc ety at the Astor Hotel in New York in October, 1916. We have been recognized as the authority on technical matters in the motion picture industry and our proceedings, which are issued twice a year, are much in demand for reference. We should continue in our efforts and should include all branches of the industry which should be represented and through this means we should materially increase our membership.

Those who attended our last meeting in Cleveland well remember the instructive and interesting papers which were there read and discussed. Our transactions are now assuming goodly proportions and it is hoped that complete copies of the transactions will be kept convenient for reference.

I am not going to take up much of your time during this session, but I do want to bring two points to you which I feel should be kept constantly in mind; namely, standardization and cooperation.

STANDARDIZATION

One of the drawbacks of the motion picture industry, and this is the experience of all new engineering bodies, is the lack of standardization. We have a very resourceful field before us and while we have made a good beginning, I know we all feel that our activities along this line should increase with each succeeding meeting. Let us, in our recommendations, keep in mind the practical as well as the technical viewpoint, inasmuch as the two go hand in hand. It is very difficult to estimate the dollars and cents that are wasted each year on account of the lack of standardization and likewise it is equally difficult to estimate the savings that we may effect by our efforts to standardize.

COOPERATION

Commercial competition should have no bearing on any papers which we present or discuss. Let us consider why we have become members of The Society of Motion Picture Engineers. Is it our sole wish to join the Society for what we individually can get out of it, or is it our purpose to take a part in the development of this growing industry; to achieve the highest standards in order to materially benefit thereby? Cooperation and good feeling among our members are the only things that will bring the desired results.

The period since the organization of our Society has been a trying one. The whole world has been at war and the period has been one of industrial development rather than of engineering

development and we have all been too busy producing material of one kind or another to assist in winning the war. The Government at Washington has proclaimed to what extent motion pictures have assisted in making the world safe for democracy. Now that the armistice has been signed and peace conferences are being carried on, we can again divert our efforts to a greater extent to the technical fields and solve the problems of standardization which will eventually result in economies in our various departments of activity. In other words, we as engineers, also will have our problems of readjustment.

A subject which should receive our most serious consideration is the work of our various committees. They should show more activity. Members who are appointed on committees are those who are well posted on the subjects covered by the several committees. Therefore the committees are the natural channels through which should originate the problems of standardization and subjects for discussion. It would seem that much of the work of our papers committee could be eliminated if each committee would arrange for papers on subjects which it feels would be most helpful to the members.

I fully appreciate the honor which you have conferred on me by electing me your president. I want to take this occasion to thank those who so unselfishly gave their time and cooperation in connection with the Society work. The result of this meeting will be due mainly to their efforts. I hope that you will individually feel that this is your meeting and that you will leave Philadelphia with the feeling that you have not only profited by attending these sessions, but also that you have been the means of helping other members to solve their problems.

H. A. Campe.

"WHITE LIGHT FOR MOTION PICTURE PHOTOGRAPHY"

By Wm. Roy Mott

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Cleveland, Ohio

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1. INTRODUCTION

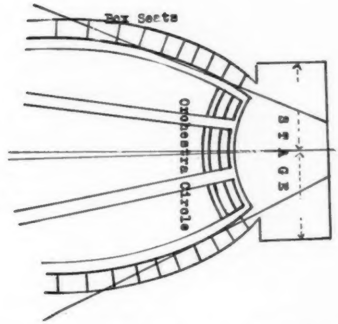
1. Relation of Motion Picture Industry to Light

The famous psychologist, Professor Munsterberg, wrote a few years ago a book on motion pictures, and he there asserted that the production of motion pictures by the best companies had graduated as an *Art* to rank coequal with painting, sculpture and music. By

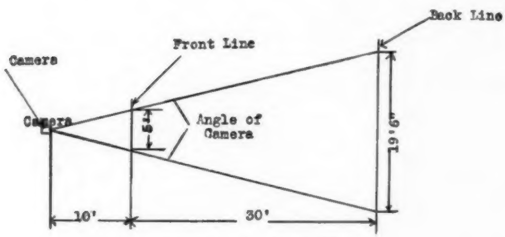
attention to mode and variation of lighting, many new psychological appeals can be made, including the portraying of the thought images in the minds of the characters of the play in a way that cannot be duplicated on the theater stage. Besides being one of the fine arts, the motion picture art has become the greatest educational institution in the world. Very special lighting is needed for scientific films, for ultra-rapid motion picture work, and for the several new color processes in motion picture production. Not only is the moving picture industry the greatest educational institution, but it is also one of our foremost industries. Since Edison's and Jenkin's invention of motion picture devices of only a score or so years ago, the industry has leaped to fourth place in the United States. There is spent annually three to four hundred million dollars by the people of the United States for the privilege of attending the motion picture theaters. The daily attendance is said to average between ten and twenty millions of people. Of the fifty thousand motion picture theaters in the world, there are about twenty thousand in the United States, and as a producing center, the United States is the greatest in the world. The *sunshine* of California has built up a major producing center in and near Los Angeles. (In this center, over $12,000,000 are annually spent for motion picture production, and this gives employment to about 25,000 people.) Again the importance of light in relation to expense of production may be judged from the following statement made by Mr. G. McL. Baynes (of the English Hepworth Mfg. Co., see Moving Picture World, page 2334, December 25th, 1915); "As to photographic difficulties encountered in outdoor work in England, it is ridiculous to say that they cannot make pictures there. *It is true, production is more expensive, perhaps twice as much because we have to wait for the Sunshine.*" Thus in foggy England, the difficulties are much greater on account of poor light than in the West or East of the United States. The invention of the high amperage white flame arc lamps and carbons and of other artificial light sources such as the daylight gas filled tungsten lamps and the mercury arc lamps, have eliminated these expensive waits for sunshine. The home-center of the motion picture industry in the East is again building up rapidly. These new studios are especially to be found in or near New York City, and to a lesser degree near other large centers of population, as for example, Chicago, Philadelphia, Cleveland, etc. Scenic interest, such as at Ithaca and in Florida, is another industrial factor in the location of motion picture plants. The increase in artificial light facilities has been an important economic factor in this Eastern movement which is being accelerated by the continual increase in the extraordinary salaries which are paid the motion picture artists. The cost of production of an average negative of one reel is said to be about $1,000, and of this it is certainly economy to spend one or two per cent. on securing the best lighting.

1-B. LIGHTING DIFFERENCES BETWEEN THEATER STAGE AND MOTION PICTURE STAGE

The lighting differences between the theater stage and motion picture stage are illustrated by Fig. 1, which shows that the theater stage



Floor plan showing theatre stage is very shallow, and has a decreasing width of Back-Ground.



Plan of Motion Picture Stage showing increased depth of Back-Ground

FIG. 1—Theater Stage Compared with Motion Picture Stage

has a broad front line, below which come the footlights, and then a *very shallow back-ground* because the essential action of the stage must be visible to everyone in the audience on both sides of the auditorium. On the other hand, the motion picture photographer can select any point of view, and this necessarily has an enlarging background in the usual case of real scenery. The camera lines in the ground view (Fig. 1) represent limits outside which the lighting units must be placed, except for trick flame lamp used to imitate lanterns and house lamps. In the vertical plane exactly the same rule must be followed in regard to increasing height of overhead lamps for the background. The excellent results from footlights has not yet been appreciated by the motion picture artists.

I-C. ARTISTIC RELATION TO LIGHT

Motion pictures only became commercially successful for entertainments when it became possible to select a subject, stage it with all the startling realism of the spoken drama, and give its photog-

raphy those qualities perhaps best connoted by the term "portraiture." For portraiture effects—Rembrandt, line lighting, etc., control of the position, direction and diffusion of light is necessary. Some lighting forming an oblique angle on the face to the camera gives increased reflection, and aids in preventing flatness. For artistic results, the white flame arc is distinctly superior for securing modelling, atmosphere, definition, half-tone and fine photographc quality in the negatives. Mr. Max Mayers, in his valuable paper on "Artificial Light in the Motion Picture Studio," given at the Rochester meeting of our Society, says "Back lighting is a splendid way of obtaining pleasing and natural results. This is effected by placing the lights well back and directing them toward, but not at the camera, masking the direct rays at the lamp, and preferably using a shielding tube with perfectly dull black interior over the lens barrel, to prevent halation. Thus the figures and objects in the set will be silhouetted, and by the proper front arrangement of reflecting surfaces and well diffused lights at a fair distance, the features and details may be perfectly modelled in shadow, with pleasing highlight relief effected by the rear lights." Later sections will treat further of artistic possibilities with the new lighting means.

I–D. IMPORTANCE OF GREAT INTENSITY OF LIGHT

A large amount of light is required in motion picture work, because of the short exposures (1/30–1/50 sec.), and need for definition. The pictures are only 1" x ¾" in size on the celluloid film. These are magnified over 10,000 times in area on the screen and therefore need to be taken with greatest sharpness. There are sixteen pictures per foot and these sixteen are moved through the camera or projecting machine in about one second. (A thousand feet or 16,000 pictures are called a reel and take about fifteen to twenty minutes to run through the machine.) Each picture is brought into exact position with a closed shutter. This shutter is then opened for about 1/30 of a second and the exposure is made. (In case of projection, the eye in this period receives the full impression of the picture and by persistence of vision retains the image perfectly for the next 1/20 of a second during which the shutter is closed and the screen black and the next picture exactly placed.) In the interest of definition and depth of focus, it is highly desirable to work at small lens opening. For instance with the white flame arc lights *f* 5.6 is often used in motion picture studios whereas *f* 4.5 and even *f* 3.5 have been recommended with other sources of artificial light. Some of the flame lamps, with their reflectors and and diffusing screens, can be used to give a light intensity of 10,000 and more candles per square foot, so that even daylight is surpassed if so desired. We will now consider daylight.

The moving picture industry is the only industry dominated geographically by the question of light. While in ordinary artificial lighting 5 and 10 foot-candles is good illumination, yet on the moving picture stage at least a hundred times this should be used. This means a stage illumination of 500 to 1000 foot-candles as a minimum.

2. Daylight

The larger the number of days of good clear sunshine, the lower is the cost of motion picture production, because of the saving of time of high salaried artists. But little has been done as yet to use artificial light in conjunction with *outdoor scenes* for which daylight is ideal except for the interruption of the photography by dark, cloudy days. (In England some use of arc lamps has even been made for outdoor scenes). Even on consecutive clear days there may be a large variation in actinic light as shown in Fig. 2. (See page 128, Sheppard's Photo-Chemistry.)

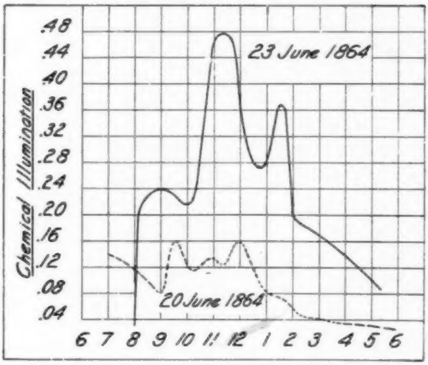


Fig. 2—Daily Variation of Photographic Light with Daylight

For interior scenes daylight must be diffused to avoid outdoor appearances caused by the direct shadows from the sunlight. This diffusion is secured by using prism glass in the roof and sides of the studios. If the studio work for interior scenes is done outdoors then awnings of light sheeting or muslin are used to secure proper diffusion and this is sometimes done in studios with glass roofs, especially if clear glass has been used. A serious objection to daylight in such studios is the hot-house effect, especially in summer. As these glass houses receive continuously one to two horse power of solar energy per square yard of projected area normal to the light, the heating effect is many times greater than with good artificial light alone, because the full amount of artificial light is used intermittently and seldom for more than a total of an hour a day. The artificial light (used generally for side illumination) with daylight should be given by the light of the greatest photographic power in proportion to the energy liberated in the studio. For this reason flame arcs are commonly used with daylight. In the winter daylight is rather poor after penetrating the glass and screening and so dependence is then largely placed on the artificial light. This seasonal variation and hourly variation of sunlight

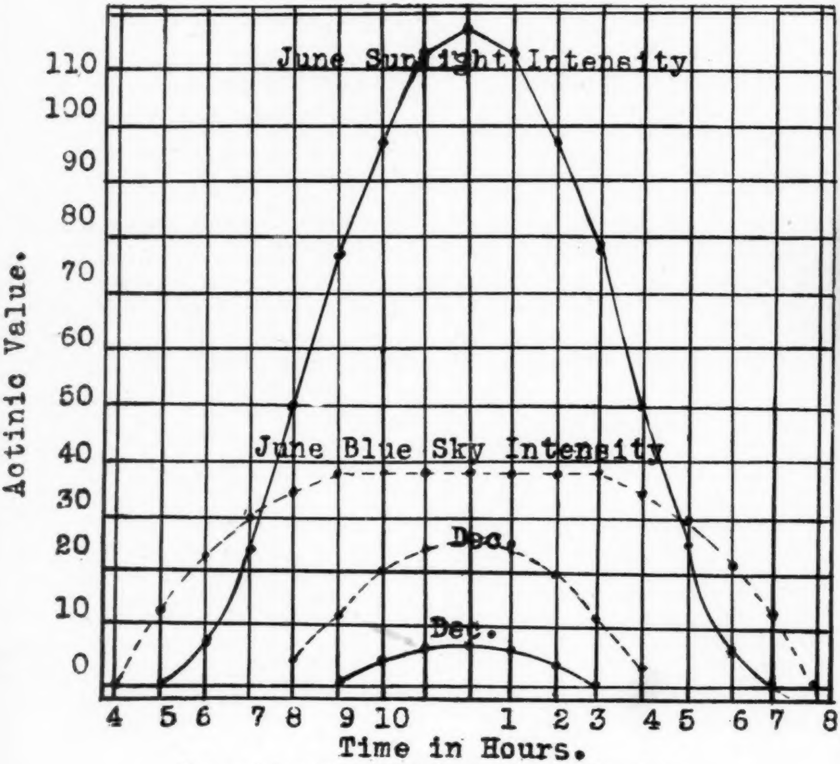


FIG. 3—Average Daily Variation for June and December

and skylight is shown in Fig. 3, taken from Eber's Handbuch der Photographie. Again the changing direction of sunlight has been a serious objection and the studio, known as the Black Maria, of the Edison Company was arranged on wheels so that it could be moved to face the light.

Finally there is one class of interior scenes for which daylight in any form is entirely unsatisfactory. This is in night scenes where sharp shadows and brightly illuminated parts must come in the same picture. Again all motion picture work in actual interiors such as subways, mines, caves, hotels, theaters, churches, etc., must be done with artificial light. This brings us to the vital importance of artificial lights. And of these the closest to daylight photographically is the light of the white flame high amperage arc lamps which will next be considered.

3. WHITE LIGHT FROM THE FLAME ARC

3–A. SPECTRUM

The white flame high amperage arc gives a light which is re-

markably close to daylight in both color and photographic values. Like daylight the spectrum is not entirely continuous, but the effect of being practically continuous is obtained by the enormous number of light giving lines in every part of the spectrum, including the ultra-violet which with the white flame arc is very similar to that given by sunlight.

In Fig. 5 is shown in the outer parts the spectrum of a white flame arc (25 amperes) in the region photographically important

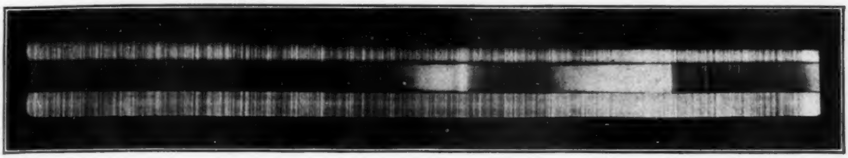


FIG. 5—Spectrum—Outer Two Snowwhite Flame Arc—Inner Carbon Arc No Flame Material

for the common materials. The pure carbon arc for the same region is shown by the middle spectrum which has marked gaps between the cyanogen bands (the cyanogen bands are due to the reaction of carbon and nitrogen at high temperatures). This duplication of daylight is so good and the intensity of light is so great that this light is being used by large clothing concerns as a reliable substitute for daylight in making dye fading tests. In fifty hours of testing with the flame arc, dyes are faded to the same degree as by about three weeks of ordinary daylight in June in Cleveland. The white flame arc is also used for color matching.

3-B. PSYCHOLOGICAL VALUE OF COLOR OF LIGHT

It is a part of the higher management of motion picture producers to give the actors and actresses a background of reality and not of ghastly unreality. "The living interpreter must have the living scene to do his best." And so it is now recognized by motion picture producers that pleasant scenes need pleasant light in order to get the best out of the artists, as witness the use of music. White light is the best for ordinary drama and comedy. A blue or blue-green light is especially good for very sad scenes, such as death-bed scenes. Mr. Edward L. Simons (Trans. I. E. S. 6, p. 295, Jan. 1911), at a time even before the use of flame arcs, pointed out the effect of blue-green light on the actors by saying "but without the arc lamp, it would be pretty hard to go through a real love scene, because everybody would look sick." Hence the value of the red content of the white light is of great importance to motion picture productions (although photographically of no value for ordinary purposes), it is of value in giving the artists a suitable environment for their best artistic expression. Much of the modern film is sensitized to long wave lengths and then the red and yellow light are important.

3–C. RELATION OF COLOR TO "MAKE-UP" AND FILM SENSITIVENESS

In make-up the motion picture artist soon learns that red will photograph black because the ordinary film is not sensitive to red light. For this reason the make-up of a moving picture artist should not have rouge on the cheeks (and it is best to avoid having gold-filled teeth). On the other hand an excessive amount of white clothing should be avoided as this may give rise to halation which results in a blur. Hence yellow, gray and other colors of clothes are used. This halation needs to be watched carefully with the lights having low latitude on the photographic plates. It is interesting to note that the light of the white flame arc shows a very wide latitude on films. This means the picture will show parts highly lighted and dimly lighted with clear definition.

In regard to film sensitiveness the ordinary motion picture film has a maximum sensitiveness in the violet with considerable sensitiveness in the blue and ultra-violet and much less in the green and yellow, and no sensitiveness in the red. Some motion picture laboratories are making orthochromatic films fairly sensitive to yellow light. For panchromatic photography and color photography, of course, all parts of the light are used. Because of the use of a yellow screen with these, special flame carbons can be used not only to give more light, but such light that a screen of better transparency can be used. This, of course, is very important because color photography film calls for a great deal more light for motion picture work than ordinary films. For motion picture production the yellow flame carbons with special screens have been found very good. Calcium fluoride is used and gives a spectrum rich in red and green bands with very little spectrum yellow.

3–D. AMOUNT OF LIGHT IN RELATION TO CURRENT

The flame arc shows a rapid increase in actinic light with increase in current. In fact the flame arc with doubling of the current at the same arc voltage increases its photographic effect not twice but three to four times. This makes it profitable to use the flame arcs at high amperages of 15–25 to 35 amperes. In some cases much higher amperages have been used. The effect of amperage on amount of actinic light is shown in Fig. 6, which also shows the advantage in effect that the flame arc has over the enclosed ordinary arc. These sets of curves in Fig. 6 were obtained with single arcs on 110 volt circuit, but with the new type of flame arc having two arcs in series on 110 volts the efficiency of the flame lamps is often increased from 40 to 60% over that of a converted lamp with a single flame arc on 110 volts. The enclosed arc lamp soon reaches a limit of current because of the dangers to globe melting down or if a very large globe is used then the amount of air at the start decreases the initial efficiency, which is very important in motion picture work because the actual scenes are short and usually last from ten seconds to a minute or two. On a 220 volt circuit, it is now customary to use 2 or 4 flame arcs in series and this compares favorably with the 220 volts enclosed arc lamps under average con-

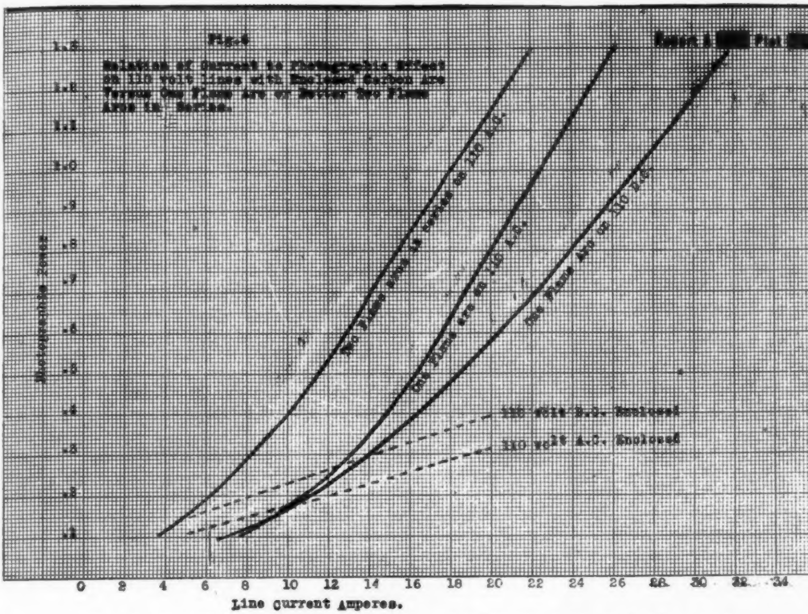


FIG 6—Relation of Current to Photographic Effect on 110 Volt Lines with Enclosed Carbon Arc versus Single and Twin Flame Arcs

ditions. From a series of tests of a direct current flame arc lamp, I have deduced the following approximate equation for photographic efficiency as regards effect on solio paper for a single direct current flame arc. C is current and V is arc voltage within moderate limits (40 to 80).

Photographic efficiency $= KC^{1.8} (V-23)$

On alternating current efficiency increases as $C^{2.2}$

The flame arc also increases in candlepower more rapidly than the current, but this phase of the matter does not need to be enlarged upon here. The color of light increases toward the short wave lengths faster than the long wave lengths with increase in current. With increase in current the blue light increases more than the green and the green more than the red.

3-E. AMOUNT OF LIGHT IN RELATION TO ARC VOLTAGE

We will very briefly consider the relation of photographic effect on solio paper to arc voltage (see Fig. 4) keeping the current constant. The following results were obtained by using a 330 volt direct current circuit with the trim of a 10 mm x 305 mm lower flame positive and a 12½ x 305 mm upper (½ x 12″) cored enclosed arc standard negative upper. The data shows the great advantage of using two flame arcs in series on 110 volts. The working equa-

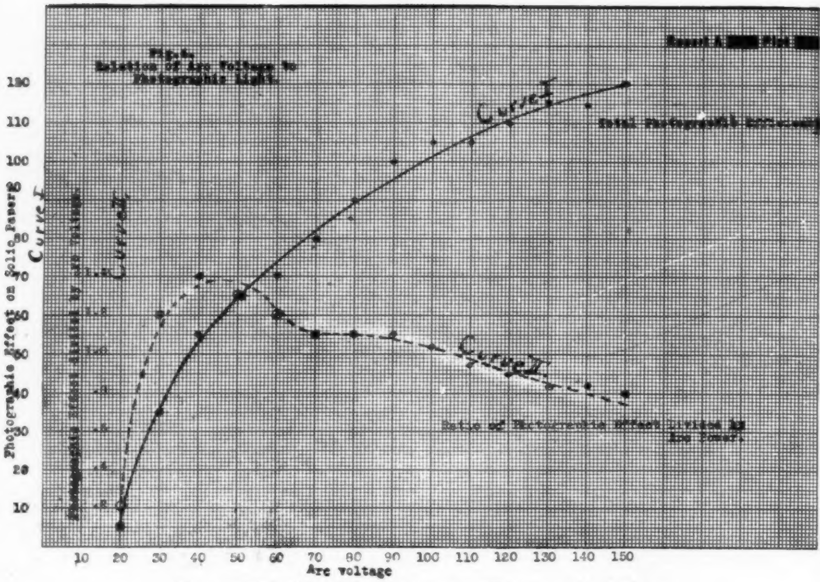


FIG. 4—Relation of Arc Voltage to Photographic Light

tions of the data can be reduced to the following approximate, empirical formulas.

1st, from 0 to 60 arc volts at 25 amperes,

Photographic Power $= 5.1\ V - 78 - .044\ V^2$

From 60 to 150 arc volts at 25 A

Photographic power $= 1.47\ V - .0045\ V^2$

TABLE I

Volts Col. A	Photographic effect on Solio paper Col. B	Energy efficiency $\left\{ \frac{\text{B Photographic effect}}{\text{A Arc voltage}} \right.$
20	5	.2
30	35	1.2
40	55	1.4
50	65	1.3
60	70	1.2
70	80	1.1
80	90	1.1
90	100S	1.1
100	105	1.05
110	105	.95
120	110	.9
130	115	.85
140	115	.85
150	120	.80

S means standard of reference.

Analysis of the above table shows that the use of two flame arc in series is very efficient. This also has other advantages namely that the power factor can be raised on A.C. from about .90 with a single arc to even .95 for the twin arcs. Also the volt ampere characteristic is materially improved so that as much as nearly 90% of the line power taken can be thrown into the flame arcs even on multiple circuits of 110 volts with satisfactory steadiness.

3-F. RELATION TO NUMBER AND POSITION OF ARC

With two flame arcs in series on 110 volts steady operation can be secured with 45 volts at each arc or with 90 volts of the 110 line volts in the light producing arcs. With a single flame arc on 110 volts about 60 volts are used in the arc so that the twin arcs have about 50% better power utilization over the single arc. Also the power factor and arc stability are improved by operating two or three flame arcs in series on 110 volts. It is not practical to operate more than a single enclosed arc on 110 volts because its starting arc voltage of 40 volts is over twice as great as the starting arc voltage of the flame arc of 15 to 20 arc volts. This difference is further illustrated in Fig. 7, showing an Aristo enclosed arc lamp, the same converted to burn flame carbons and the twin arc Wohl lamp. (This Fig. 7 was prepared by Mr. Ben Perris.)

A vertical flame arc is generally preferred, but the arc will burn well in a great variety of positions. In general, flame upper carbons and flame lower carbons are used in motion picture flame lamps so that the lamps can be used on either direct or alternating current and without any regard to polarity if it is direct current. This

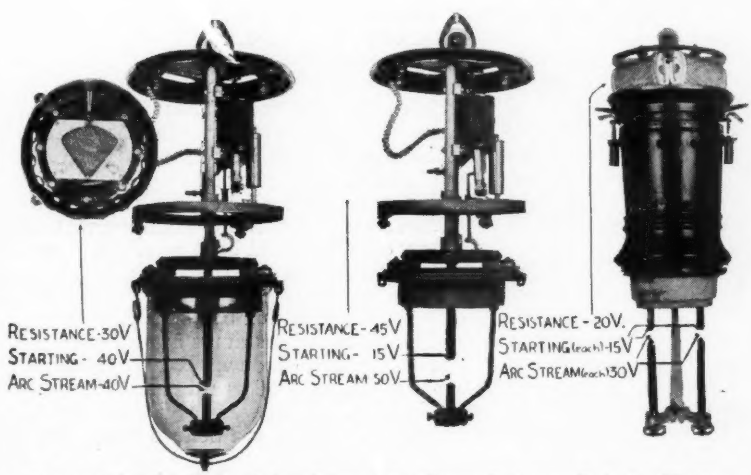


FIG 7—Aristo Enclosed—Aristo Converted to Flame Carbons—Twin Arc Wohl—Shows Voltage Distribution

arrangement is different from the photoengraving field where a very common trim is a neutral enclosed arc upper carbon with a *white flame positive lower*. In this case the flame carbon must always be made positive because the flame chemicals travel through the arc stream from the positive crater to the negative crater. It is the flame materials that produce the light and wrong polarity or pure carbon open arc gives about one-sixth the photographic light of the white flame arc. However, a positive flame upper carbon gives better efficiency with a flame negative lower as against a neutral negative lower.

On alternating current, both carbons should be flame carbons, as here the flame material feeds from both electrodes, and so this arrangement gives the maximum efficiency. The use of reactance ballast on alternating current lamps in place of resistance ballast increases greatly the efficiency of a white flame arc for equal power in the arc, and gives from 50 to 100% more light for equal power on the line. With reactance ballast on two or three flame arcs in series on 110 volts, the overall power factor is better than .85. Three flame arcs in series on 110 volts with metal coated carbons gave but very little if any more efficiency than two flame arcs in series.

We will now consider some of the typical flame lamps used in motion picture studios.

4. Rapid Developments of High Amperage Flame Lamps

4-A. DESCRIPTION OF SEVERAL TYPES OF FLAME LAMPS

Special flame lamps have been developed to operate on A.C. or D.C. and in series on 220 volts or in multiple on 110. This makes the lamp of universal use, and calls for no special attention to the electrical conditions. The resistance of the flame lamp to mechanical shocks, electrical shocks such as overvoltage and to bad weather conditions, has made it universally used for outside (of studio) motion picture work. Combined with all these advantages is the remarkable small weight of these lamps. For instance, some of the twin arc lamps weigh no more than 20 pounds for lights giving 8,000 or more horizontal candlepower, and with the light of a little greater actinicity than daylight. The amount of light is probably greater in proportion to weight than any other artificial light used in motion picture studios. Further improved design can greatly reduce this weight.

We will now show briefly figures of a number of typical high amperage flame lamps. The following flame lamps are commonly used in motion picture work: Allison and Hadaway, Aristo, Bogue, Chicago Stage Lamp, Joyce, Klieglight, Macbeth, Scott, Simplex, Sunlight, Universal, Wohl and others. As there is no article or book where these types have been shown collectively, I believe the following figures will be of interest.

The Aristo lamp, Fig. 7, is an enclosed arc lamp which has been much used by portrait photographers and in motion picture studios.

The motion picture studios now use in the Aristo lamps, white flame carbons ½ x 12″ upper with a ½ x 6″ lower *with or without the globe*. The greater diffusion of the light and reliability of the flame arc immediately found great favor with the photographers of motion picture concerns when demonstrated a few years ago by Mr. A.D. Spear, June, 1912, at Edison studio. The amount of light with 28-A and 63 arc volts with flame carbons was 5130 *mean spherical candlepower* in the tests in our laboratories at Cleveland.

The Allison and Hadaway lamp is a twin arc designed especially for portability in a suitcase form. There is also made by this company, a diffusing cabinet with flame lamp and a small amateur flame lamp with shunt control to greatly raise the current at the time of taking the pictures. The horizontal candlepower of the 15 ampere flame lamp is said to be 8,000. Fig. 8 is a hanging lamp of the Allison and Hadaway type.

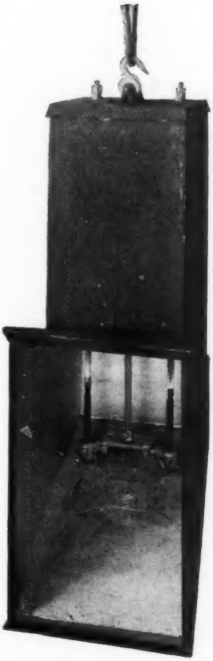


FIG. 8—Allison and Hadaway Twin Arc Hanging Lamp

The Chicago Stage lamp, Fig. 9, is unusual in having the flame carbons at right angles.

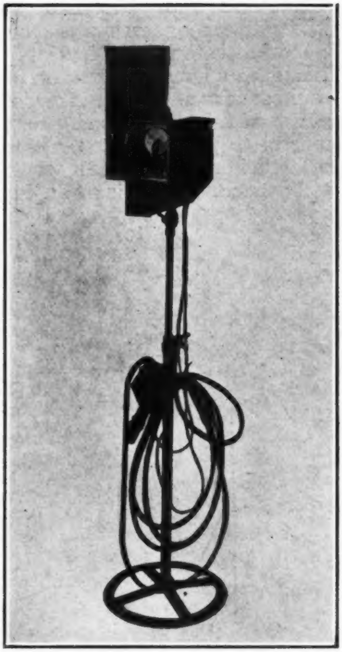


FIG. 9—Chicago Stage Lamp

The Joyce flame arc lamp has been used somewhat in industrial moving picture work.

The Klieglight, Fig. 11, is a high amperage (30 to 40 amperes) lamp, *with horizontal carbons*. The lamp is mounted on a pedestal with casters, and is used for side lighting. The lamp is very powerful, and so is usually diffused by a large glass screen. A low weight lamp with vertical flame carbons is also made. The portable Klieglight is shown in Fig. 10.

The Macbeth Co. is well known in the photo-engraving field, and have recently produced a tilting lamp, which is apparently of considerable greater efficiency than their usual photo-engraving lamp. The lamp is designed so that the light can be directed to any part of the stage, both vertically and horizontally. The tilting lamp is designed to burn on A.C. and D.C. and, in case of 220 volts, two in series.

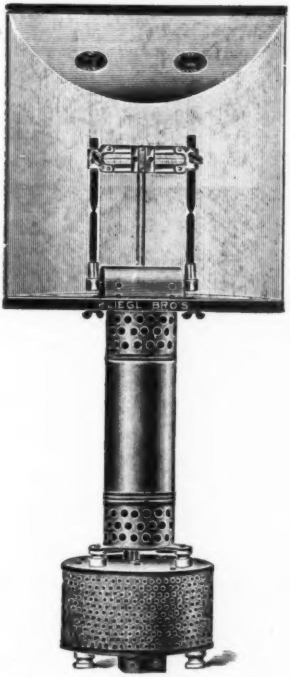


FIG. 10—Klieglight Portable

FIG. 11—Klieglight Stand. 25-35 Ampere with Horizontal Flame Carbons

The Scott lamp, Fig. 12, is a revival of the inclined gravity feed lamp at 15 to 20 amperes, and has two arcs in series in each lamp.

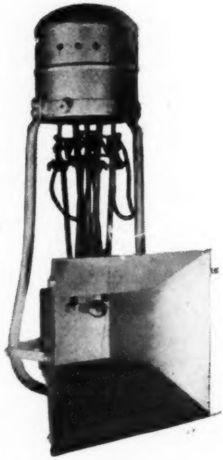


FIG. 12—Scott Hanging Lamp, 15-20 Amperes—Inclined Trim Twin Arcs

This lamp is especially used for overhead lighting, and in a stand form for side lighting. These lamps give a greater effect by 40% than some of the flame arcs having only one arc on 110 volts.

The Simplex lamp is a twin flame lamp which is very portable and can be carried around in a suitcase. This lamp is designed for 15 to 25 amperes.

The Universal or Majestic lamp has two flame arcs in series, and these are placed next to the economizer. The lamp can easily be directed to throw its light to any part of the stage.

The Wohl Duplex hanging lamp is shown in Figs. 7 and 13. This lamp has two flame arcs in series, and our laboratory tests show a mean spherical candlepower of 6,700 with no reflector with the lamp taking 30 amperes on 115 line volts (direct current.) With the reflector, the horizontal beam candlepower is 22,000, according to tests made by Mr. Perris of our laboratory. In motion picture studios these lamps are provided with suitable woven glass diffusing screens or large tracing cloth diffusing screens. The Wohl Broadside, Fig. 14, is a stand lamp taking 30 amperes with four arcs in series on 220 volts or 60 amperes on 110 volt line with two pairs of series arcs. A very portable low weight lamp is also made. A complete description of all the American lamps would fill a book, so we will pass on to foreign lamps and spot lamps.

The foreign makers of white flame lamps have lagged considerably behind the American manufacturers. An English flame lamp

called Truelight, is interesting because four arcs are used in series on 220 volts, with the current reversing direction at each arc and carbons changing size to maintain a focusing effect. Some of the early

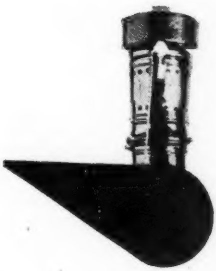


FIG. 13—Wohl Overhead

FIG. 14—Wohl Stand Lamp

German flame lamps are shown in Eder's Handbuch der Photographie, page 452. They can be of no importance compared with the American lamps.

Another type of flame lamp is the spotlight lamps operated usually by hand. These are used in the same way as the ordinary theater spotlight lamps, but unlike the theater lamps, the carbons used should be the white flame photographic carbons or the white flame searchlight carbons. Some movie directors have told the

4–B. TABLE OF WHITE FLAME LAMPS USED IN MOTION PICTURE STUDIOS

Flame Lamp	Amperage	Chief Lamp Characteristics	Flame Carbon Trims Upper	Flame Carbon Trims Lower	Number and Position of Flame Arcs
Allison & Hadaway	15 A–25 A	Suitcase Portable	½ x 4″ W. F.	⅜ x 4″ W. F.	Twin Vertical
Aristo	28 A	Converted Enclosed Arc	½ x 12″ W. F.	½ x 6″ F. W.	Single Vertical
Bogue	25 A	Stand (Photo-engraving)	½ x 12″ W. F.	½ x 6″ W. F.	Single and Twin Vertical
Butler Super Power	15 A to 55 A	Widely Adjustable Amperes	½ x 12″ W. F.	½ x 6 ″ W. F.	Single Vertical Adjustable
Chicago Stage Lamp	25 A	Right Angle	⅜ x 12″ W. F.	½ x 6″ E. A.	Right Angle Arc
Converted Enclosed Arc	15 A to 70 A	Shunt Adjustable	½ x 12″ W. F.	½ x 6″ W.F.	Single Vertical
Joyce Flame Arc	25 A	Stand (Photo-engraving)	½ x 12″ E. A.	⅜ x 12″ W. F.	Single Vertical
Klieglight	15-30-40 A	Portable and Heavy Stand	½ x 4¾″W. F.	½ x 4¾″W.F.	Twin Horizontal
Macbeth Tilting	25 A	Stand Tilting	½ x 12″ W. F. (A. C.)	½ x 12″ W.F.	Single and Twin Arc Tilting
Scott	15–20 A	Inclined trim	⅜ x 11-32″x12″ W.F. (D.C.)		Twin Inclosed Trim
Simplex	15–25 A	Suitcase Portable	½ x 4″ W. F.	⅜ x 4″ W. F.	Twin Vertical
Stage Spotlight	50–100 A	Spot lighting	½ x ⅝″ x 6″ W. F.		Single Flame Spotlight
Sunlight	120–150 A	Searchlight	⅝″ x 12″ W. F.	½ x 7″ W. F.	Flame Searchlight
Universal	15 A	Tilting	⅜ x 12″ W. F.	½ x 12″ W. F.	Twin Arc Tilting
Wagonhoarst	30 A	Reactance A. C.	½ x 12″ W. F.	½ x 6″ W. F.	Twin Arc Vertical
Wohl Tilting	25 A	Portable Tilting	½ x 6″ W, F.	½ x 6″ W. F.	Twin Arc Tilting
Wohl Duplex	30 A	Side and Overhead	½ x 12″ W. F.	½ x 5″ W. F.	Twin Arc Vertical
Wohl Broadside	30–60 A	Powerful Stand	½ x 12″ W. F.	½ x 5″ W. F.	Four Arcs Vertical

Abbreviations: A = Amperes. W. F. = White Flame. E. A. = Enclosed Arc.

writer that using the white flame photographic carbons increased the photographic light about six times compared with ordinary projector carbons. The white A.C. projector carbon is not as efficient for studio lighting as the white flame photographic carbon. The flame searchlight has also entered the motion picture field with great success. It is often operated fifty feet away, and with currents of 120 to 150 amperes. We will next consider homemade flame lamps. Electricians in motion picture studios have to continually devise new effects for simulating lanterns, indoor lamps, fires, etc. In general, it is a great mistake to make an article if it can be found on the market; but there are times when it is an advantage to know how to make a flame lamp out of other lamps. This we will next consider.

4-C. CONVERSION OF ENCLOSED ARCS TO FLAME LAMPS

For some purpose a cheap lamp with adjustable current for changing the amount of light is convenient. In Figs. 15 and 16 are

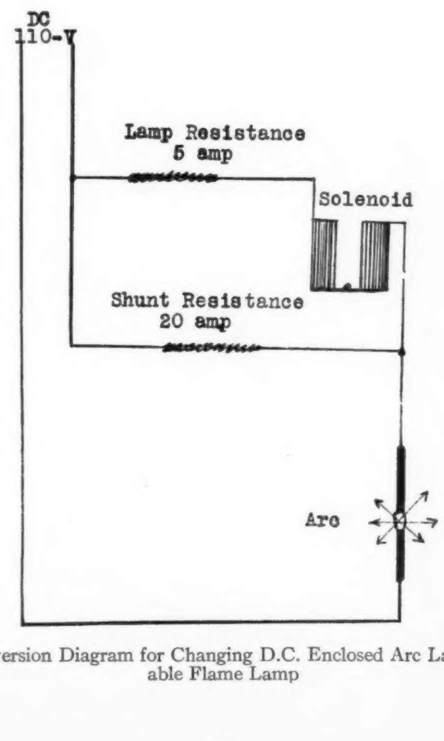


FIG. 15—Conversion Diagram for Changing D.C. Enclosed Arc Lamp to Adjustable Flame Lamp

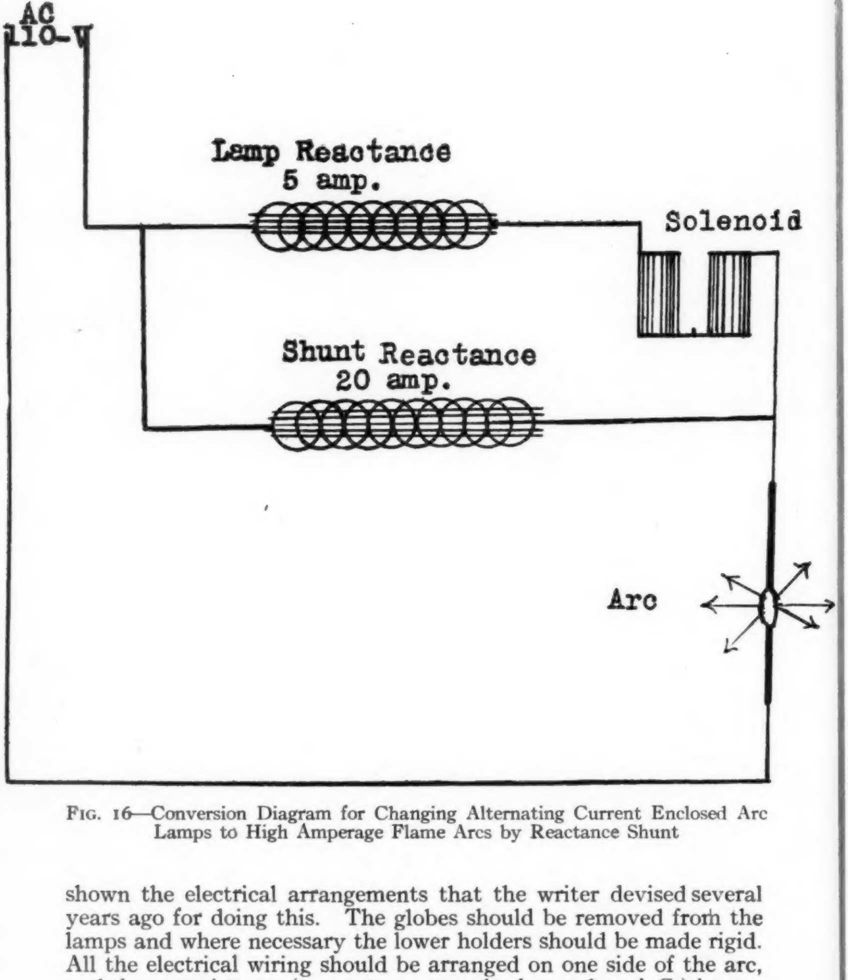


FIG. 16—Conversion Diagram for Changing Alternating Current Enclosed Arc Lamps to High Amperage Flame Arcs by Reactance Shunt

shown the electrical arrangements that the writer devised several years ago for doing this. The globes should be removed from the lamps and where necessary the lower holders should be made rigid. All the electrical wiring should be arranged on one side of the arc, and then a resistance (or reactance can also be used on A.C.) is connected in shunt to carry 15 to 20 amperes at 50 volts around the lamp resistance and solenoid ordinarily taking only 5 to 7½ amperes. Half-inch white flame carbons, metal coated at the holder ends, give excellent results. It is easy to work two converted enclosed arc lamps with the two flame arcs in series on 110 volts.

4-D. LONG LIFE MULTIPLE TRIM ARRANGEMENT

A long life multiple trim arrangement for photographic white

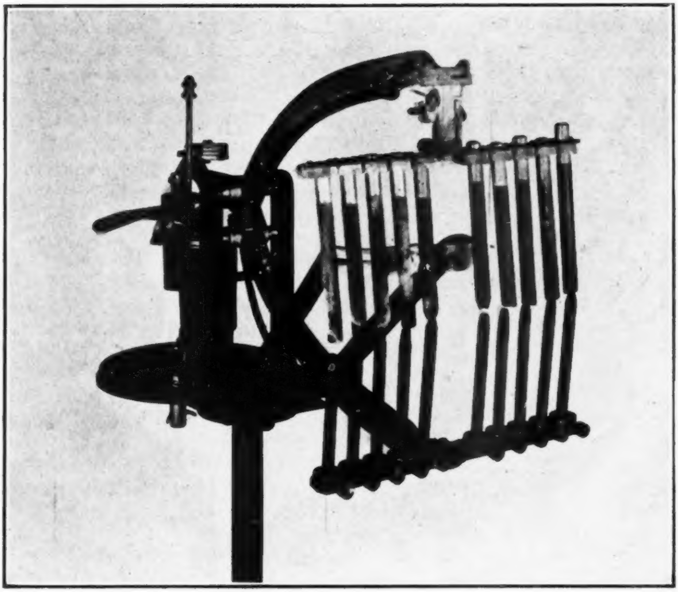


FIG. 17—Long Life Multiple Trim Arrangement

flame lamps is shown in Fig. 17, where a holder having ten trims was operated on a Macbeth photographic engraving lamp with its reflector detached. For many purposes doubling the trim would have great advantages, and the writer believes a number of arc lamp companies will shortly put out lamps with multiple trims. They would be especially useful for overhead lighting and for blue printing.

We will now turn to the consideration of the flame carbons which are the heart of the light production. A picture of the flaming arc is shown in Fig. 27.

5. Motion Picture Flame Carbons

The chief carbon used for photo-engraving and photography is the white flame carbon of which over a million a year are now being sold for this class of work. In the larger sizes a special star shaped core is used. The color of the light can, where necessary, be changed to suit the exact requirement without buying a new lamp or even a new screen, because other flame carbons of different colors are available for these lamps when they are needed. The white flame is strictly a snowwhite light with a spectrum (Fig. 5) full of lines in its every part. This is most generally used. The pearl white is a light a little more suited for panchromatic and color photography. The

color of its light is very close to that of ordinary sunshine. The yellow flame carbon gives a light rich in red and green, but having comparatively little spectrum yellow or blue. The sensation of yellow light is produced by the combination in the eye of the red and green light. The violet in this light is fairly strong. The red flame arc gives a light rich in red and in spectrum yellow, and has a fair amount of blue. The so-called "blue" flame carbons are designed to be especially rich in far ultra-violet beyond 3000° Angstrom units. This far ultra-violet is practically absent in sunlight and likewise in the white flame arcs ordinarily used in photographic work. The near ultra-violet light is very important photographically with sunlight and skylight, and with the white flame arcs. The ultra-violet of the white flame is largely in the region longer than 3500° Angstrom and it efficiently goes through ordinary glass.

An important improvement has been the use in photographic lamps of metal coated flame carbons, especially on the holder end. This metal coating reduces the holder drop in voltage from about half a volt to 1/20 of a volt so that a holder designed for 5 ampere use can, with metal coated carbons, be used at 20 and 30 amperes with long, excellent service.

American white flame carbons, both in our tests and those throughout the United States have shown 10 to 15 per cent better efficiency of light and longer life on the average than the foreign carbons. This is because of superior knowledge and skill that the American carbon manufacturers have as regards the making of these flame carbons. This condition of superiority has been maintained for several years.

6. Discussion of General Advantages of the White Flame Lamps for Photography

The following ten points repeat a few of the advantages of the flame lamps for photographic artists; the greatest efficiency; best color duplicating daylight; instant response when the current is turned on; less unsteadiness from fluctuating line voltage; wearing part of smallest cost per unit; most rugged to all kinds of mechanical and electrical abuse and to adverse weather conditions; lowest cost of installation and operation; can be used for spot lighting or with screen for diffuse lighting or with reflector for indirect lighting; largest candlepower per single unit and maximum portability in proportion to candlepower.

7. Special Lighting Effects

In considering the lighting of moving picture studios, we will consider first over-head lighting and then side lighting. In regard to *overhead* lighting there are two classes—diffuse and concentrated. The diffuse lighting is often obtained in the glass studios by use overhead of flame arcs which occupy only a small area and allow considerable of daylight to enter the scene. The concentrated overhead lighting is secured by mounting in a large reflector a score of

FIG. 18—Aristo Lamps with White Flame Carbons at Edison Co. (This was the First Moving Picture Company to Use White Flame Carbons. Mr. A. D. Spear First Demonstrated the Use Here in June, 1912.)

FIG. 19—Edison Studio Lighting with Blue Bulb Gas Filled Incandescent Lamps

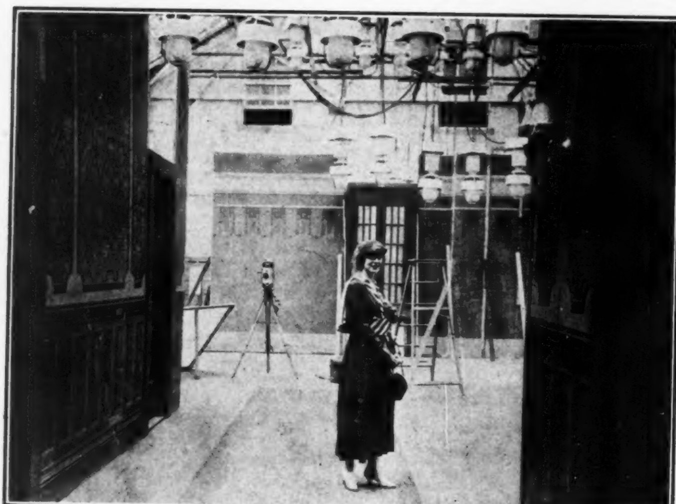


FIG 21—Miss Anita Stewart Redeeming Light Setting at Vitagraph

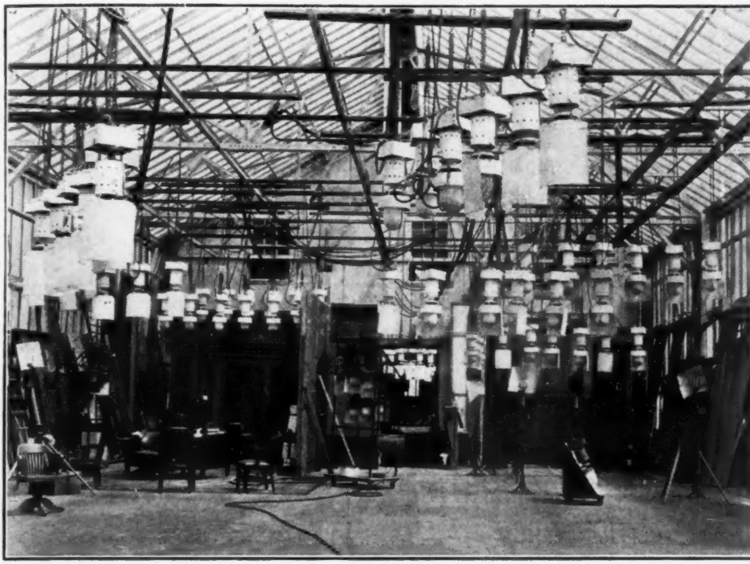


FIG. 20—Typical Studio Setting for Two Scenes at the Vitagraph Co. Using Flame Lamps Designed by Mr A. Ross. Twenty Flame Lamps at 20 Amperes are Used for Average Set

flame lamps or by the use of very powerful spot light or flame searchlight. In overhead lighting with flame arcs for the Edison studio

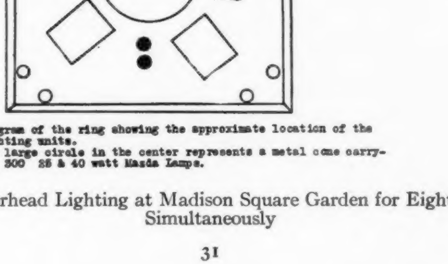


Diagram of the ring showing the approximate location of the Lighting units.
The large circle in the center represents a metal cone carrying 300 25 & 40 watt Mazda Lamps.

FIG. 22—Overhead Lighting at Madison Square Garden for Eight Cameras Simultaneously

is shown in Fig. 18, and for the Vitagraph studio in Figs. 20 and 21. In Fig. 19 there is shown overhead lighting with the blue bulb daylight incandescent lights in the Edison studio. Other modes of lighting are shown in Figs. 22, 24, 25 and 26.

For *side lighting* powerful flame lamps on stands with wheels are universally used. A well known illumination expert for motion pictures, Mr. Mayer of Wohl & Co., states that the best lighting for moving picture stage is ordinarily given by using 50% more side lighting than top lighting, and that the so-called L arrangement

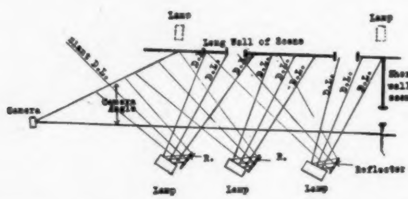


FIG. 23—Typical Side Lighting for Usual L Scene

(Fig. 23) is generally more effective for lighting than the box arrangement. The side lighting should have contrast to give the proper perspective. The angular sweep of the camera is usually such that the distance from camera divided by two gives the width of the operating field (close-ups of 4 feet cover an approximate width of 2 feet.)

The diagram, Fig. 23, illustrates roughly, the *L* arrangement. In this arrangement there are shown the long wall of the scene to the short wall with the camera opposite the short wall and a number of side lights. The overhead lighting is not shown. Small reflectors are used with the side lamps to give slant light coming back toward the camera, but of course *not into it*. This gives a good reflection on surfaces sidewise to the light because the light is reflected so obliquely that a large amount is carried to the camera from side surfaces, and this arrangement gives the much desired line and Rembrandt effects, or as better known to the motion picture artist as molding and modelling effects. The working area of such a stage is therefore bounded by the long wall and short wall and the camera line, outside of which the lights must be. The distance outside should be sufficient to avoid harsh changes due to inverse square law.

The use of real scenery in place of painted scenery gives, of course, the best results. Real scenery should be lighted from the side. Painted scenery should be lighted directly from the front with the light striking nearly perpendicular. If the scene is set up with painted scenery, two sets of lighting should be used, one for the foreground and the other for the painted scenery. This same principle applies to panorama where near objects are lighted in one way and the panorama in a different way to give suitable blending of the illusion.

In lighting it is well to get a suitable blending of the direct light and of the diffuse light. Nature's rule is half and half. The diffuse light is so advantageous in cutting out the harsh sharp black shadows and giving what is known technically as luminous shadow effects. Diffuse light can be secured by indirect light as well as by diffusing screens. The intensity of the light should photographically be very high in order to get the camera to operate satisfactorily with *f* 5.6. The flame arc can be used with a camera lens at *f* 5.6 to give good lighting on a small stage with 20 kw. The jump from *f* 5.6 to *f* 4.5 or even *f* 3.5 makes a big difference in the definition and clearness of the picture. The depth of focus can be maintained better, of course, with *f* 5.6, and because of the important artistic value of the background and the large distances with rapid movements that should be covered, it is highly desirable to work with a good depth of focus. With the flame arc the high concentration of light can be easily controlled as well as the direction of light. This convenience of control of the amount and direction of light are necessarily of the highest importance for free artistic expression on the part of the directing geniuses. In general, the motion picture stages will use with flame arcs the following amount of powers having the lens at *f* 5.6.

Small	Stage	20 kw.	4 to	6	flame	lamps.	
Medium	"	50	" 10 "	16	"	"	(See Fig. 1)
Large	"	100	" 20 "	32	"	"	

Using the larger openings of lens *f* 3.5 as low as 20 kw. with flame arcs can be used to secure the illumination of large stages. As the amount of light varies with the reflecting surfaces and is inversely as the square of the distance from the light sources it is not easy to give exact information without going into too elaborate detail. Also multiple reflection can in partly closed spaces greatly increase the illumination. (See Fig. 25 and 26.)

The artistry of the motion picture field is advancing so rapidly with so many new and complex changes that it is rather hard for an amateur like myself to keep track of even their main drift. Among the recent innovations has been the production of plays with the background subdued so that instead of the usual "close-up" the faces of the players in tense scenes are accented throughout the entire production of the play. As, for example, in the play "The Golden Chance." In this case, the background is subdued to such an extent that the characters in the foreground appear to stand out in steroscopic relief.

In another arrangement an intensely lighted background is used to cause the players to stand out in sharp shadow-like relief. In still other cases the immense control of intensity of light gives a power of securing the sudden appearance or disappearance of an actor in trick and dramatic pictures and to aid greatly in securing such peculiar effects as double exposure and other photographic tricks. The lighting can be utilized in such a way that the artistic forming of the picture is accented in harmony with the idea involved. Another way in which flame arcs are used is for casting shadows in trick pictures and to represent prison scenes in the more artistic

manner of showing the shadows of the prison bars rather than the actual grim stolid fact.

It would not be expedient to describe in elaborate detail the many devices for rapidly moving the lights around in studios or the particular mechanical arrangement for carrying the lamps around on wheel cabinets or on trolleys or on ropes, etc. The actual installations of lighting are arranged in a great variety of ways, in some cases the overhead lighting is set up with the idea of permanently supplying the particular set. In other cases the overhead lighting is arranged so as to be easily moved by a trolley system from set to set. In the latter case the small weight of the flame lamps in proportion to their candlepower greatly reduces the cost of the moving system and also affords a better utilization for admitting overhead daylight if this is desired. For side lighting the flame lamps are mounted on wheel stands either separately or in powerful unit groups of 6 and 12. The typical Edison stage is shown in Fig. 19 and 20, which were most kindly supplied by the Edison Co. Here about 28 lamps of Aristo type are seen mounted in 4 rows of 7 each. These are arranged to be easily moved. One large stand lamp is shown in this picture, Fig. 18. *It is interesting to note that the resistance of the flame lamp can be mounted in a separate room so as to further reduce the heating which is remarkably small with the flame lamp.* In some studios a dozen Aristo lamps are mounted in a portable cabinet formed in sets of three rows of four each with the top row forward and the bottom row back away from the stage. The whole can be easily moved around the studio because mounted on wheels.

In Fig. 22 there is shown the overhead arrangement of flame arcs and mercury arcs used for lighting a boxing match at Madison Square Garden. (See Lighting Journal *4*, p. 78, Apr. 1916.) It is interesting to note that eight motion picture cameras were used simultaneously and that the entire room was so well lighted that brilliant illumination was obtained in every part of the large hall.

The use of flame arcs is carried out on an extensive scale in the Vitagraph motion picture studio located in Brooklyn, New York. Mr. Ross, master mechanic of the Vitagraph Co., was kind enough to furnish me data showing that the average number of flame lamps (20 amperes each lamp) used per set is twenty. In the Brooklyn studio alone, there are 225 flame arc lamps, hanging overhead, or in sets in stands or mounted so to be easily moved about in small carriages so as to eliminate shadows. In Fig. 20 there is shown a portion of one of the main studio rooms. In Fig. 21 is shown a setting of lighting arrangements received through the kindness of Miss Anita Stewart. In Fig. 24 and 25 are some interior studios that illustrate the use of multiple reflection to increase greatly efficiency and to give diffuse light.

Mr. Cecil B. DeMille, director of the Jesse L. Lasky Feature Play Co., wrote about three years ago, an article ("Motography 15, p. 240, Jan. 29, 1916") under the title "Lighting to a Photoplay is Like Music to Drama." He concludes that lighting effects as applied to motion pictures assume precisely the same value in the

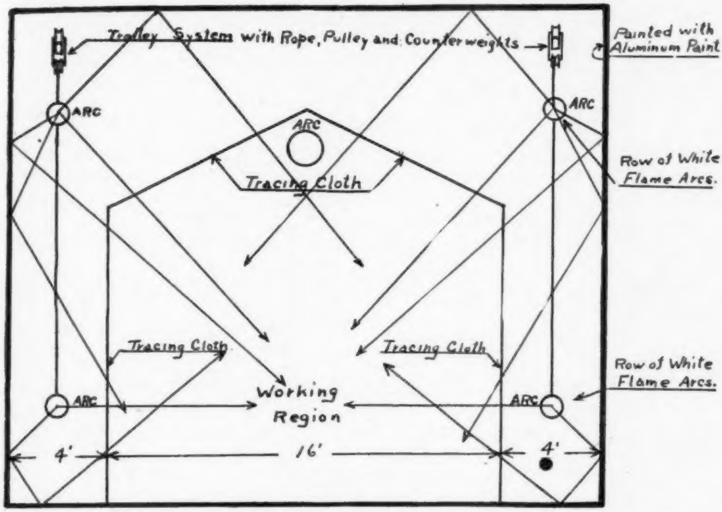


FIG. 24—Interior Room for High Efficiency Lighting by Multiple Reflection

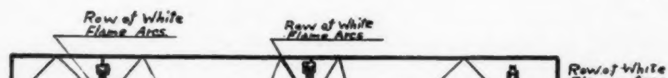


FIG. 25—Interior Room with Side and Top Diffuse Lighting with Flame Arcs

photo drama that music assumes in the spoken drama. He says "the theme of a picture should be carried in its photography." "The Cheat," representing unprincipled sinister Japanese characters, used abrupt bold light effects to definitely suggest the "clang" and smash of Japanese music.

In "Carmen," however, the Rembrandt idea was followed. The lighting and grouping of the characters in the soft shadows were all worked out in keeping with the school of that famous master. "Light effects are out of place in comedy; there you will notice our lighting is clear and brilliant corresponding to the faster light comedy and music, except in the melodramatic scenes where we carry our audience into thrills not only by the action of the artist, but by a change in the mode of our photography."

8. Looking to the Future

In conclusion, many new flame lamps have been invented and developed in the last year or two, and now varieties of flame carbons for special effects are available for a multitude of simple or complex artistic effects. However, only a small beginning has been made as to the artistic effects counting merely the minor factors of control such as direction of light, its diffusion, change of intensity and the power by proper color and environment to greatly aid the motion picture actor-artist. There is the subject of "catch-lights" in the eyes of the players that represent the reflection of the light sources. If the light sources are rectangular in shape, then the catch-lights will be rectangular or triangular, and with sharp curve points. The bad effect of not using round or oval light sources is easily appreciated. It is well recognized that curved lines convex to each other tend to give a sorrowful, depressed look. Curved lines concave to each other tend to give a pleasant, agreeable, smiling look. By attention to the shape of the diffusing screen for the light sources, it would seem possible to vary this element so as to be in harmony with the ideals of the play. All the recent motion picture photoplays of the best companies show the power of white flame arc lighting to give fine definition, splendid half tones, luminous shadows and favorably shaped "catch" lights.

In some portrait studios the light of the flame arc is thrown upon the ceiling (Fig. 26) or a reflecting screen, and in this way some very beautiful pictures have been photographed. The possibilities of indirect lighting with the flame arc have only been touched upon. By suitable lamp design, it seems practical not only to get more diffuse light, but also greater candlepower delivered to the working plane. Again in the matter of regulation, the shunt control (see Figs. 15 and 16) is one of the important future developments that will enable the artists to secure a wide variety of new effects.

The experiments with multiple trim lamps, Fig. 17, show how long life (long period between trims) can be secured for the flame arc.

On alternating current efficiency can be greatly increased with the flame arc by reactance control.

In the matter of studio lighting, the writer believes with Mr. Allison, that interior rooms lighted entirely by artificial light have

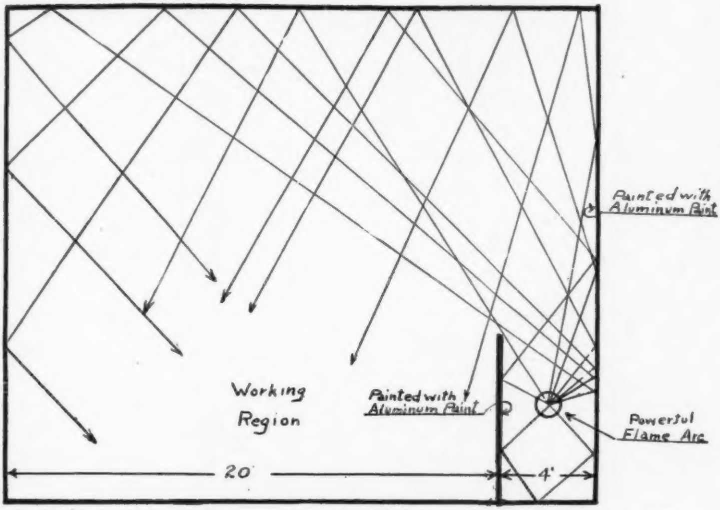


FIG. 26—Interior Room with Entirely Indirect Light with Flame Arcs

splendid advantages, because the lighting can then be entirely controlled by the artist, and the extremely hot atmosphere of sunlight glass studio is entirely done away, and a nice cool comfortable studio can be maintained throughout the year. The director can then obtain all diffuse light, all direct light, or any proportion and direction of diffused and direct light under perfect control, and old Kiny Sol with his changing position, will be entirely unnecessary for all interior scenes. In conclusion this article has pointed out mang new developments, and has indicated the promise of many others in development of different colored flame carbons, and a great variety of motion picture flame lamps.

Finally, it is my privilege to express my great indebtedness to many who have so kindly contributed time, suggestions, and photographs to this paper. I am indebted to Mr. P. P. Bethea for aid in many long experiments on the flame arc, to Mr. A. Broggini for assistance in securing many of the photographs, to Mr. Ross, master mechanic of Vitagraph, and Miss Anita Stewart for pictures from the Vitagraph Co., to the Edison Co., and to Mr. Bechwith of the Reserve Photoplay Co. for pictures, to Mr. Max Mayer (of Wohl & Co.) for friendly suggestions, to Mr. Allison, Mr. J. E. Brubec, and to many others who have so materially contributed to the value of this paper.

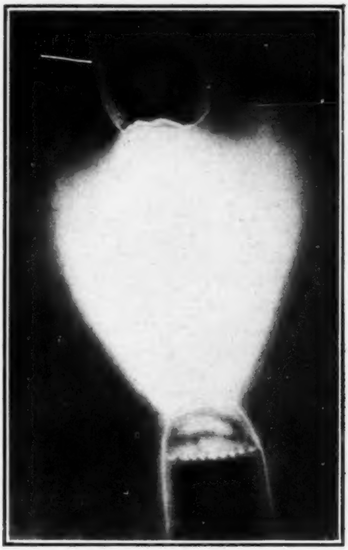


FIG. 27—Photograph of a White Flame Arc

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3. H. H. Reeves. Gen. Elect. Rev. vol. 17, p. 413, April 1914.
   Theater Stage Lighting.

4. V. A. Clark. Elec. Wld. vol. 64, p. 956, Nov. 14, 1914.
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5. M. Luckiesh. Elec. Wld. vol. 64, p. 954, Nov. 14, 1914.
   Blue Bulb Tungsten Lamps for Photography.

6. Unsigned. Elect. Rev. and West. Elect. vol. 64, p. 461, March 7, 1914.
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7. Unsigned. Electrical World, vol. 65, p. 322, Jan. 30, 1915.
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Articles on Blue Bulb Gas Filled Incandescent Lamps in Motion Picture Studios.

10. M. Luckiesh. Trans. Ill. Eng. Soc. vol. 10, p. 149, 1915.
Blue Blub Tungsten Lamp in Photography.

11. Voege, Zeit. f. Beleuchtungswesen, vol. 21, p. 33, March 1915.
Actinicity of Various Light Sources.

12. L. G. Harkness Smith. Elec. Wld. vol. 65, p. 1,040, April 24, 1915.
Flame Arc Lighting and Mercury Arc Lighting in Motion Picture Studios with Lamp Diagrams.

13. William A. D. Evans. The Illuminating Engineer (London), vol. 7, p. 284, June 1915.
A very complete article on mercury arc lighting for motion picture studios.

14. J. E. Williamson. Trans. Ill. Eng. Soc. (London), vol. 7, p. 403, July 20, 1915.
Quartz Mercury Arcs in Submarine Photography.

15. Scientific American, vol. 113, p. 83, July 1915, p. 317, October 1915, p. 393, Nov. 6, 1915.
"Black Maria" Rotated to Face the Sun.
Portable Lighting Plants.
Mercury arcs are used at 100 watts per square foot of floor space.

16. L. A. Jones, M. B. Hodgson and Kenneth Huse. Trans. Ill. Eng. Soc., vol. 10, p. 963, 1915.

PHOTOGRAPHIC EFFICIENCY AT LIKE CANDLEPOWER

Source	Ordinary Plate	Artho. Plate	Panchromatic
Sunlight	100	100	100
Skylight	181	155	130
White flame light	287	234	215
Clear bulb gas filled	64	68	76
Blue bulb gas filled	108	99	106
Mercury vapor	316	354	273
Mercury arc nultra glass	218	195	165

17. C. E. Kenneth Mees. Trans. Ill. Eng. Soc., vol. 10, p. 947, 1915.
The Electrician (London) vol. 76, p. 167, Nov. 5, 1915.
Artificial Illuminants for Use in Practical Photography.

18. W. R. Mott and V. A. Clark. Lighting Journal, vol. 3, p. 224, November 1915.
Lighting Journal, vol. 4, p. 15, January 1915.
The White Flame Arc Lamp in the Photographic Studio.
19. Ernest A. Dench. American Photography, vol. 9, p. 572, October 1915.
Colors in Staging Interiors of Motion Picture Studios.
20. G. McL. Baynes. Motion Picture World, p. 2,334, Dec. 25, 1915.
Lighting Difficulties in England.
21. Ernest A. Dench. Book on Making of the Movies, Pub. 1915.
Lighting with arcs is discussed, pages 12, 38 and 90.
22. Cecil B. DeMille. Motography, vol. 15, p. 249, Jan. 29, 1916.
"Lighting to Photoplay is Like Music to Drama."
23. W. E. Brewster. Gen. Elec. Rev., vol. 19, p. 186, March 1916.
Blue Bulb Tungsten Lamps in Photography.
24. W. R. Mott. Jour. Cleveland Eng. Soc., p. 281, March 1917.
The Characteristics and Uses of the Flaming Arc.
25. V. A. Clark. Elect. Rev. and West. Elect., vol. 68, p. 1,024, June 3, 1916.
White Flame Arc for Portrait Photography.
26. W. R. Mott. Trans. Amer. Electrochem. Soc., vol. 28, p. 371, September 1916.
Use of the Flame Arc in Paint and Dye Testing.
27. Benjamin Grass. Electrical Age, vol. 49, p. 25, September 1916.
Lighting of Motion Picture Studios.
Mercury arcs and flame arcs are discussed.
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28. W. R. Mott. Trans. Am. Electrochem. Soc., vol. 31, p. 365, April 1917.
Trans. Am. Electrochem. Soc., September 1918.
The colors and light production of different elements in arc are discussed in relation to arc images.
29. Max Mayer. Trans. Soc. Motion Pict. Eng., p. 18, April 1918.
Artificial Light in the Motion Picture Studio.
This is a very practical discussion of the use of white flame arcs and studio arrangements.
30. John W. Allison. Trans. Soc. Motion Pict. Eng., September 1918.
All interior lighting is recommended with discard of the hot-house effect of the glass-studio and control of light for *standardization*.
31. Karl Shiller. Motion Picture Magazine, vol. 17, p. 66, March 1919.
Flame arc lamps for after dark photography, outdoors and indoors, for moonlight effects, for fireside effects and for war scenes. Night scenes are lighted by concentrating the arc light on central figures and leaving the surroundings in darkness in order to give the natural and romantic effect desired.

32. Kenneth Macgowan, New Republic, vol. 12, p. 188, Sept. 15, 1917.

Formerly the motion picture studios gave the effect of flat, almost footlight scenes but the new effect—an American made device—introduce natural lighting from windows, doorways and lamps. This enables sharp staring shadows to be produced in scenes of terror or soft luminous shadows to stimulate the pleasing evening lighting. Again the new lighting can be so arranged to concentrate on the acting and avoid the effect of camera consciousness which is introduced by the old camera for concentrating the attention on the actors. He says that art in the motion pictures arises chiefly from sequence of pictorial impressions but more especially from lighting atmosphere.

SOME PHASES OF THE OPTICAL SYSTEM OF THE PROJECTOR

By F. H. Richardson

For the past twelve years we have been engaged in the study of the practical optics as applied to the motion picture projector. Through observation, we discovered that the projection lens of our projector did not pick up the entire light beam, whereas others that had lenses of equal diameter did pick up the entire light beam.

Some projectionists and theorists claimed that the beam beyond the aperture plate converged, while others, like myself, claimed that the beam diverged. We were both right; the difference being that the principal image of the arc crater was in the first case somewhere in or near the center of the projection lens, whereas, in all of my experience, the principal focus was at the aperture plate.

In order to obtain some data on this question, we employed John Griffith, Ansonia, Conn., to assist and to him the industry owes much for the very excellent work he has done in giving to it the first really workable data existent for enabling the projectionist to handle his projector optical train intelligently.

Briefly stated, the experiments which we undertook were chiefly to demonstrate that the beam from the condenser diverged between the aperture plate and projection lens when the arc crater was imaged at the aperture and this divergence was in proportion to the diameter of the condenser and inversely proportional to its distance from the aperture.

In Fig. 1 this theory is set forth diagrammatically. The whole condenser ray is indicated by the upper and lower converging dotted lines. Line B, drawn from the upper edge of the condenser to the lower edge of the aperture opening, and line A drawn from the lower edge of the condenser to the upper edge of the aperture opening, if continued beyond the aperture, marks the confines and shows the shape of the ray between the aperture and projection lens. Granting Fig. 1 to correctly illustrate what actually does take place, it is then readily understood that, condenser diameter remaining constant, the further the condenser is located away from the aperture the less will be the divergence of the beam between the aperture and the projection lens; conversely, the closer the lens to the aperture the greater will be the divergence, the exact effect of increased condenser distance being illustrated in Fig. 2.

In Fig. 2 the upper drawing illustrates the conventional method of showing the optical train of the projector. Insofar as it applies to arc light projection in practice, it is entirely wrong. The center drawing shows the effect were the condenser located 9⅜ inches from the aperture, with point of greatest concentration at the aperture. At 2 inches B. F. the projection lens would have to be 1.75″ in diameter to accommodate the entire ray. At 5.5″ B. F. it would have to be 3.75″ in diameter. The lower drawing shows the effect with the condenser at 15″ from the aperture, while the

Diagram showing how the back focus and the size of the aperture of the objective lens determine the distance between condensers and anerture.

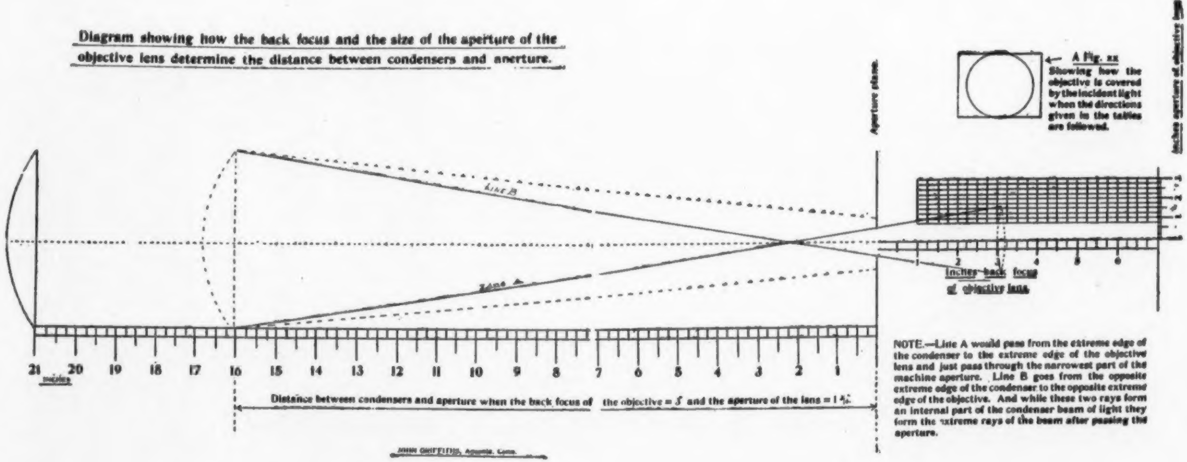


FIG. 1

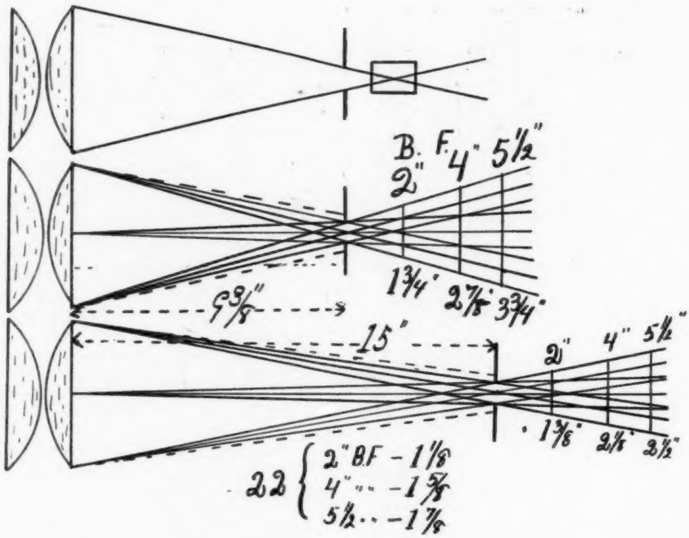


FIG. 2

figures below show the effect with the condenser at 22″ from the aperture.

Fig. 3 shows us the condenser covered by a metal plate in which two small holes are drilled, just inside opposite diameters of the condenser lens. The plate rests against the front surface of the

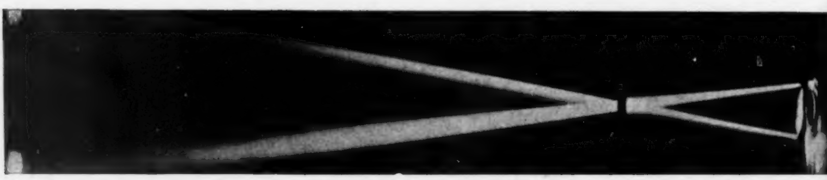


FIG. 3

FIG. 4

front condenser lens. A standard motion picture projector aperture plate is mounted on a metal plate and is placed at the crossing point of the rays, hence at the point of greatest concentration of the condenser beam. This experiment shows that, with the aperture located at or ahead of the point of greatest concentration of the condenser beam, the beam does diverge beyond the aperture.

In Fig. 4 we have still further proof of the divergence of the beam under the conditions named. Fig. 4 is the same as Fig. 3, except that the metal plate has been removed and the projection lens set in place.

We have thus shown that the ray does diverge beyond the aperture when the aperture is at or ahead of the point of greatest concentration of the condenser beam, and that the divergence is in exact proportion to the diameter of the condenser and inversely proportional to its distance from the aperture.

There is, however, a theory still tenaciously adhered to by some that the point of greatest concentration (often incorrectly called the crater image—incorrectly, because, due to the fact that the crater is neither a flat surface or parallel to the lens, it, the image, actually is in focus in its various parts through a considerable length of the condenser beam) of the condenser beam should be advanced to a point between the factors of the projection lens, as is the correct practice in stereopticon projection. Those who have given the matter exhaustive study, from the practical as well as the

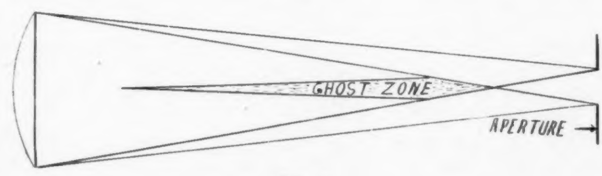


FIG. 5

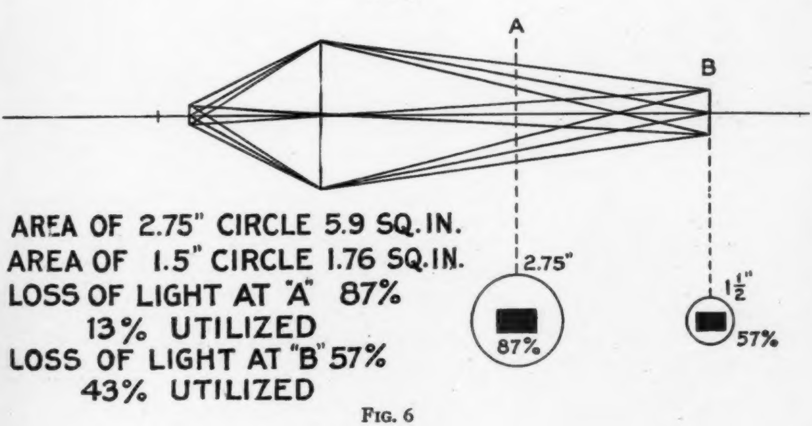


FIG. 6

theoretical point of view, however, realize that stereopticon projection, in which the object to be projected lies at the front plane of the condenser, and motion picture projection, in which the object to be projected lies a considerable distance from this point, presents two very different problems. In theoretical optics it may be perfectly right to locate the point of greatest concentration within the projection lens, but any practical projectionist will tell us that in arc light projection of motion pictures it is not satisfactory. There are several reasons for this, two of which I will name: First, it is not practical because of the fact that the advancement of the point of greatest concentration to any considerable distance beyond the aperture brings the aperture into the "ghost zone" (the condenser light ray being, as a whole, made up somewhat as shown in Fig. 5), which sets up a ghost in the center of the screen. This alone is quite sufficient to prevent the advancement of the point of greatest concentration much beyond the aperture. Second, as will be seen by a glance at Fig. 6, the waste of light at the "spot" incident to advancement of the point of greatest concentration ahead of the aperture is very great and increasingly so as the advancement increases. This, while not making the advancement of the point of greatest concentration to the projection lens impossible, does make it impractical on the score of cost.

Before leaving this phase of the subject let me remark that whatever theorists may contend, the fact is that practical projectionists find it impossible to get desired results in arc light projection with the point of greatest concentration advanced appreciably beyond the aperture.

The before described experiments proved to us two things conclusively, viz.: (a) With arc light projection of motion pictures and the optical train adjusted according to universally accepted practice, the light beam does diverge beyond the aperture in exact proportion to the diameter of condenser and inversely proportional to its distance from the aperture, as before set forth. (b) If the divergence of the ray be such that its diameter is greater than the diameter of the opening of the projection lens at the plane of the back focus of the projection lens, then the practical effect is to reduce the diameter of the condenser, and thus waste light, which, of course, means wasted electrical energy and coal. And since the diameter of projection lenses working with a brilliant source of illumination is limited by the fact that it must work in conjunction with the revolving shutter of the projector, this loss becomes a very serious matter where long focal length projection lenses are used. The amount of reduction of condenser diameter may be determined, in any given case, by extending lines B and A, Fig. 1, to meet the edges of the opening of the projection lens at its point of back focus.

Based on knowledge obtained during the aforenamed experiments, supplemented by exhaustive study of the whole proposition, John Griffiths proceeded to compile for us a series of lens tables and charts, finally culminating in the one recently published and shown in Figs. 7A and 7B.

These tables and charts have as their basis the minimum distance it is possible to locate a crater of given amperage, under normal,

average working conditions, to a condenser lens without undue lens breakage; in other words on the practical limit of heat a condenser lens will stand under normal working conditions. They also are calculated on the equivalent focus of the condenser combinations named when the factors are so placed that their apexes (plano con-

FOR MENISCUS BI-CONVEX CONDENSERS

DIAM. OF OBJECTIVE				CONDENSERS		AMPERAGE
3" B.F.	4" B.F.	5" B.F.	6" B.F.	ARC	FRONT	
1.65	1.9	2.15	2.4	6½	9½	60 D.C.
				6½	9½	55 D.C.
1.6	1.8	2.1	2.25	6½	8½	50 D.C.
				6½	8½	45 D.C.
1.54	1.75	2.	2.14	6½	8½	40 D.C. 60 A.C.
				6½	8½	35 D.C
1.45	1.65	1.85	2.	6½	7½	30 D.C. 40 A.C.
				6½	7½	25 D.C.

↑ DISTANCE TO APERTURE: 16", 17", 18", 19", 20", 21", 22", 23", 24", 25", 26"

FOR PLANO CONVEX CONDENSERS

AMPERAGE	CONDENSERS		DIAM. OF OBJECTIVE			
	ARC	FRONT	3" B.F.	4" B.F.	5" B.F.	6" B.F.
60 D.C.	6½	7½	1.76	2.	2.3	2.56
55 D.C.	6½	7½				
50 D.C.	6½	7½	1.66	1.9	2.2	2.42
45 D.C	6½	6½				
40 D.C. 60 A.C.	6½	6½	1.56	1.84	2.1	2.3
35 D.C	6½	6½				
30 D.C. 40 A.C.	6½	6½	1.5	1.75	1.94	2.16
25 D.C.	5½	6½				

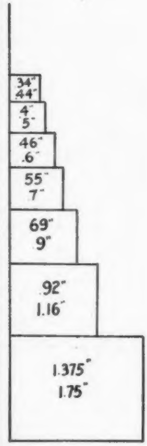
PROJECTIONIST'S OPTICAL CHART

THE AMPERAGE IN USE INDICATES THE FOCAL LENGTH OF CONDENSERS THEIR DISTANCE FROM THE APERTURE AND THE DIAMETER OF THE OBJECTIVE LENS THAT SHOULD BE USED.

Lens Chart No. 1, © 1918 by Chalmers Publishing Company

vex) are not to exceed $\frac{1}{16}''$ apart. Further spacing alters the E.F. of the combination sufficiently to seriously affect results. It must also be remarked that, while these charts and tables have already amply proven their value, there is and always will be some slight variation in application because of the fact that condenser lenses are

PROJECTION LENS E.F.	DISTANCE BETWEEN CONDENSERS & APERTURE INCHES																		
	1 2 3 4 5 6 7 8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
3"	DISTANCE APERTURE TO CONDENSER IMAGE	7"			6.75			6.6			6.5			6.4			6.3		
	HEIGHT OF IMAGE	.92			.69			.55			.46			.4			.34		
	WIDTH OF IMAGE	1.16			.9			.7						.5					
3½"	DISTANCE		8.16				7.9			7.7				7.5					
	HEIGHT		.92				.69			.55				.46					
	WIDTH		1.16				.9			.7				.6					
4"	DISTANCE				9.3				9				8.8						
	HEIGHT				.92				.69				.55						
	WIDTH				1.16				.9				.7						
4½"	DISTANCE					10.5					10.1								
	HEIGHT					.92					.69								
	WIDTH					1.16					.9								
5"	DISTANCE		12.5					11.6					11.25						.11
	HEIGHT		1.375					.92					.69						.55
	WIDTH		1.75					1.16					.9						.7
5½"	DISTANCE			13.7					12.8						12.4				.12
	HEIGHT			1.375					.92						.69				.55
	WIDTH			1.75					1.16						.9				.7
6"	DISTANCE				15						14						13.5		
	HEIGHT				1.375						.92						.69		
	WIDTH				1.75						1.16						.9		
6½"	DISTANCE					16.2						15.1							14.7
	HEIGHT					1.375						.92							.69
	WIDTH					1.75						1.16							.9
7"	DISTANCE						17.5							16.3					16
	HEIGHT						1.375							.92					.7
	WIDTH						1.75							1.16					1"



Lens Chart No. 2, © 1918 by Chalmers Publishing Company

Figs. 7A and 7B

not accurate in focal length. A 7.5 in. plano convex lens, for instance, is apt to be almost anything between 7.25 in. and 7.75 in. focal length. Also the mechanical limitations of even the most modern projectors render the application of lens tables impossible for all amperages until changes have been made in the machine. Notwithstanding these difficulties, however, the charts and tables have proven of great value to projectionists, and the industry is deeply indebted to Mr. Griffith for the work he has done along these lines.

Knowing that the beam diverged between the aperture and objective lens when the crater was imaged at the aperture, we were anxious to ascertain to what extent light was lost when the diameter of the objective was less than the diameter of the beam.

In order to obtain this data, we requested the National Lamp Works Laboratories, Nela Park, Cleveland, Ohio, to make measurements of the light flux at different points across the beam, at different distances beyond aperture and with the condenser at certain designated distances from the aperture.

In order to obtain check data, we requested the Westinghouse Lamp Company Laboratories, Bloomfield, N. J., to make similar

measurements. Both these companies were good enough to accede to our request and made the desired measurements. We desire to tender our most sincere thanks to the National Lamp Works and the Westinghouse Lamp Company for their aid in this matter.

These measurements have proven that a huge loss of light may occur through failure to properly design projection lenses, particularly those of long focal length, with maximum diameter and *short back focus*. Lens manufacturers in our opinion, have heretofore not given this hugely important matter anything like sufficient attention. In fact, aside from increase of diameter nothing at all, so far as we know, has been done by the leading lens manufacturers to design lenses to fit the obvious need, though one lens made by an obscure manufacturer has pointed the way, and has amply proven its worth. Increase of lens diameter is not sufficient to meet the situation except in lenses of short or medium focal length. Lens diameter is necessarily limited, due to the fact that projection lenses must work in conjunction with a revolving shutter. This is particularly true where a light source of great brilliancy is used.

In our opinion there is urgent need for a re-designing of projection lenses, particularly those of long focal length. Personally we believe this can only be taken care of by designing lenses which shall in no case have a back focus greater than perhaps two inches, though the exact figure we would not care to state positively without further study on that particular matter. If this can only be done by means of a three-combination lens, then we believe a three-combination lens is the thing needed.

The following results were arrived at by the National Lamp Company laboratories after an exhaustive series of measurements of the projector light beam between the aperture and the projection lens. The same measurements by the Westinghouse laboratories gave essentially identical results. We may therefore confidently say they are correct.

* * *

The following is a summary of data supplied by the National Lamp Company.

"*Object:* To determine the relative intensities of various points in various planes across the light beam on the projection lens side of the aperture plate.

Description: The optical system was mounted as indicated in Fig. 8, upon which appears the dimensions used for the six settings. The condensers were ordinary 6.5 in. and 7.5 in. foci plano-convex, 4.5 in. in diameter. The light source consisted of a small piece of opal glass over which was mounted a metal plate with a 0.5 in. diameter opening. This opening was illuminated by a Mazda projection lamp which gave us a light source without variation in brilliancy, and one which for the purpose gave practically the same effect obtained from the crater of an electric arc. Fig. 9 shows the mounting of the Weber photometer. In Fig. 8 the radiating rows of round dots are quarter

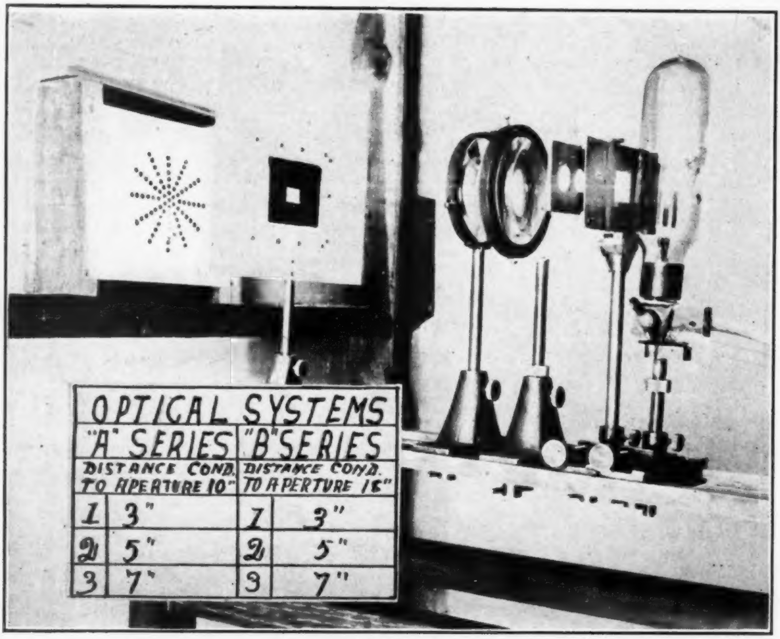


FIG. 8

inch holes in the screen, through which the measurements were made. Their opposite side is seen in Fig. 9. This screen was laid out in several "zones." The first, or center zone is a ⅜ in.

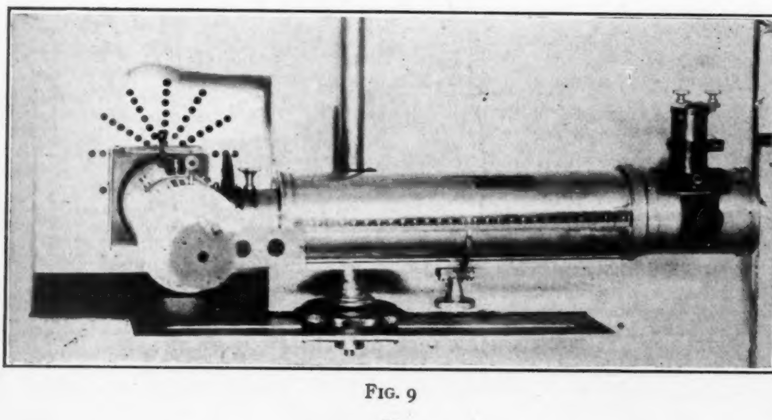


FIG. 9

circle, and each succeeding zone is 3/8 in. wide. It will be seen that this arrangement allowed of a remarkably complete measurement of the whole area of the light beam, and a very exact plotting of these measurements afterward.

Results: Following will be found tabulated results which were obtained from the test. For each test in each series the spot obtained is shown full size, and on it are indicated the zones, with the segments in the center of which observations were taken. Figures in these segments represent foot candles obtained by measurement. The chart contained in Fig. 8 shows the relation of condenser and aperture. In "Series A" the aperture was located 10 in. from the condenser. In "Series B" the distance was 18 in. Three series of measurements were made with each of these distances, viz.: at three, five and seven inches from the aperture.

Fig. 10 shows No. 1, 2 and 3 of the measurements taken in the A series (condenser 10″ from aperture) and Fig. 11 shows No. 1, 2 and 3 of the measurements taken in the B series (condenser 18″ from aperture). With each figure is given, in tabular form the calculated results.

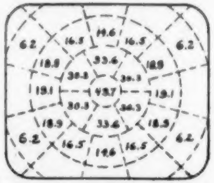
Discussion: In the first place, we have shown that with the source imaged at the aperture, the beam emerging from the aperture is diverging, the amount of divergence being proportional to the diameter of the condenser and inversely proportional to its distance from the aperture. We have also shown that a considerable portion of the light lies outside of the parallel beam from the aperture, meaning by "parallel beam" a beam of uniform cross-section equal to that of the aperture and parallel throughout its length to the optical axis. The amount of light lying outside this parallel beam, considering the area of the beam as equal to the area of the first two zones, can be readily seen from a study of Table 1.

Table No. 1

Light Outside of a Parallel Beam

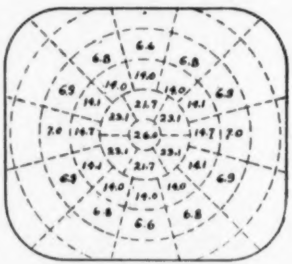
Series "A" Condenser 10 in. from aperture	Series "B" Condenser 18 in. from aperture
3 in. from aperture—60%	3 in. from aperture—40%
5 in. from aperture—72%	5 in. from aperture—47%
7 in. from aperture—76%	7 in. from aperture—57%

To get at the real significance of the above figures we must consider the area of the beam which would be covered by the opening in a projection lens, which, for the purpose of this paper, we will call 2 in. The area of the opening of the lens then would be approximately equal to the area of the first three zones, as shown in Figs. 10 and 11. Assuming, then, that the lenses used would have a back focus equal to the distances from the aperture plate used in this investigation (3, 5 and 7 in.), we find there is a large proportion of the light which would not be used by the lens, and that the quantity



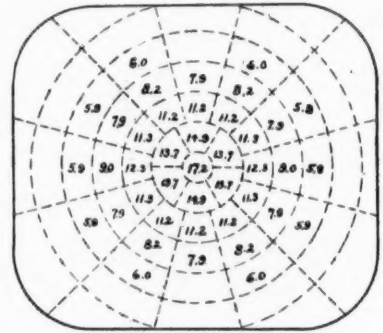
Zone	Area sq.ft	Av. F.C.	Lumens	% Total
1	.0077	43.7	.34	5.8
2	.062	31.4	1.95	33.6
3	.123	17.4	2.14	36.6
4	.113	6.2	1.40	24.0
remaining zones				
		Total	5.83	

Fig. 3.



Zone	Area	Av. F.C.	Lumens	% Total
1	.0077	26.0	.200	3.4
2	.062	22.0	1.40	24.0
3	.123	14.2	1.75	30.0
4	.183	6.83	1.25	21.5
remaining zones			1.26	21.0
		Total	5.83	

Fig. 4

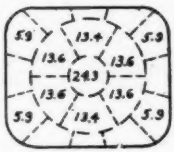


Zone	Area	Av. F.C.	Lumens	% Total
1	.0077	17.2	.13	2.3
2	.062	14.1	.88	15.1
3	.123	11.4	1.40	24.0
4	.183	8.4	1.54	26.4
5	.245	5.9	1.77	25.2
remaining zones			.41	7.0
		Total	5.83	

Fig. 5.

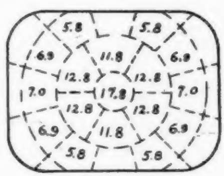
FIG. 10

increases with (a) length of back focus and (b) nearness of condenser to aperture.



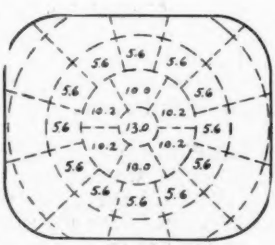
Zone	Area	Avg. F.C.	Lumens	% Total
1	0077	24 3	19	10 8
2	062	13 .5	.86	49.2
3			.70	40.0
		Total	1.75	

Fig 6.



Zone	Area	Avg. F.C.	Lumens	% Total
1	.0077	17 .8	.14	8 .6
2	.062	12 .5	.78	44.6
3	.112	6 .9	.77	44.0
remaining zones			.06	3 .4
		Total	1 75	

Fig. 7.



Zone	Area	Avg F.C.	Lumens	% Total
1	0077	13 0	.10	5.7
2	.062	10.1	.63	36 0
3	.123	5 8	.71	40.6
remaining zones			.31	17.7
		Total .	1.75	

Fig. 8

FIG. 11

TABLE No. 2

Light Outside a 2 in. Circle

SERIES "A" Condenser 10 in. from aperture	SERIES "B" Condenser 18 in. from aperture
3 in. from aperture—24%	3 in. from aperture— 0
5 in. from aperture—43%	5 in. from aperture— 3%
7 in. from aperture—49%	7 in. from aperture—18%

Table No. 2 gives the percentage of light outside the first three zones, or, in other words, outside a 2 in. circle.

Conclusion: It then is apparent that in choosing a projection lens to fit given conditions, attention must be paid to the condenser and its distance from the aperture, as well as to throw and size of picture.

For a given throw and picture size, the diameter of the projection lens which would utilize the greatest percentage of the light passing through the film would depend, to a great extent, upon the position of the condenser. With the condenser fairly well forward, the required lens would necessarily have a much larger diameter than if the condenser be located pretty far back, with consequent less divergence of the beam, but it must be remembered that the distance of condenser from aperture is automatically fixed by considerations beyond control of the projectionist.

Fig. 7 shows the location of the condenser to be variable, hence there is only one practical method left us for overcoming the tremendous loss of light incident upon using long focal length projection lenses, and that is the shortening of their back focus. This is particularly true where high amperage is used, since high amperage acts automatically to bring the condenser nearer the aperture, thus increasing the divergence.

In explanation of the large percentage of light lying outside the three central zones (2 in. circle), I would respectfully call your attention to the fact that, whereas the light flux within the central zones has much higher value per unit of area, the area of the outer zones is immensely greater than that of the central zones, which acts to even things up.

Gentlemen, in view of the fact that distance of condenser from aperture is automatically fixed by amperage, which acts to compel the use of a widely diverging beam beyond the aperture where heavy amperage is used, I am obliged to reiterate my recommendation that projection lenses be re-designed in such a way that no lens will have a back focus greater than 2 in , or at most 2½ in.

Discussion by Dr. Kellner

I had planned to speak myself to-day on the condenser subject but upon seeing Mr. Richardson's and Mr. Burrows' able and elaborate paper I decided to confine myself to a few remarks.

On account of the spherical aberration in the ordinary condenser the rays coming from the source and passing through its marginal zone intersect the optical axis much nearer the aperture plate, and under a much greater angle than the rays passing through the center of the condenser. If the diameter of the lens is not large enough it happens that some of the rays coming through the marginal zone of the condenser are not intercepted by the lens and, therefore, lost for the illumination on the screen. This is illustrated in the first figure.

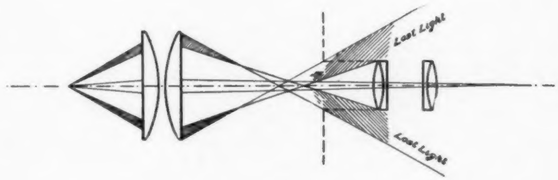


Fig. 1

Such loss may be avoided in two ways:

1st. By making the aperture of the lens large enough to collect those rays or by keeping the aperture the same as before and bringing the rear combination of the lens so close to the aperture plate that the lens intercepts the rays otherwise lost, in other words by reducing the working distance (back focus in Mr. Richardson's paper).

2d. By reducing the spherical aberration of the condenser so that rays coming through the margin of the condenser pass through the lens.

The first remedy is not very inviting to the lens computer nor to the lens maker. The greater the aperture of the lens in proportion to its equivalent focal length the more difficult it is to correct the aberration and the more difficult it is to produce the lens and also the more sensitive such lens is to small variations in the adjustment of the machine.

A lens with shorter working distance can be constructed by adding a third combination. This has the disadvantage of additional loss of light by reflection and absorption in the added member, amounting to 10% which will have to be subtracted from the amount gained by the shorter working distance.

The working distance may also be shortened in a two combination projection lens by increasing the distance between the combinations. This, however, has also difficulties of its own.

It seems to me more logical to leave the projection lens alone and remedy the evil by using a condenser that sends through the projection objective all the light which it collects from the source. For this purpose we must reduce the spherical aberration of the condenser to such an extent that the rays coming through the margin of the condenser intersect the optical axis near enough to the objective to be intercepted by the latter and thus contribute to the illumination on the screen. This is illustrated by the dotted lines in Fig. 2. The full lines show the path of the rays through the central and marginal zone of a fully corrected condenser.

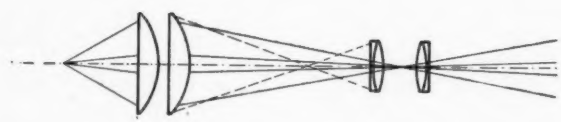


Fig 2

I have here a model of a projection apparatus which shows very nicely the condition under discussion. These are interchangeable condenser systems consisting of the same number of lenses and having the same equivalent focus and aperture. One of these condensers is spherically corrected and produces a small distinct image of the source, while the non-corrected one shows at the same distance a diffused image of the source surrounded by a broad circular halo. The outer zone of this halo which falls outside of the circumference of the projection lens is of course lost.

It is evident that with the spherically corrected condenser a lens of very much smaller diameter would be sufficient to give the same illumination on the screen as the large lens in combination with a non-corrected condenser.

I must confess that I cannot quite reconcile the figures of loss as given by Mr. Richardson and Mr. Burrows with an experience I had several years ago.

A short working distance lens was submitted to me, built especially from the view point of meeting the criticism set forth in Mr.

Richardson's paper. It was claimed that this lens showed an increase of illumination of about 100% on the screen. A comparison between this lens and a lens of the ordinary type was made in the following way:

In the booth of one of the theaters of Rochester two machines of the same make and type were placed side by side and run under as nearly as possible the same conditions using the same size carbons, keeping the current the same, etc. The fields projected by the lenses in competition could be compared side by side on the screen. Under similar conditions the new lens was supposed to show a 100% superiority in the illumination. The originator of the short working distance lens, himself, adjusted the machines, as well as for another comparison, the operator of the theatre and afterwards a third impartial person. It goes without saying that the objectives also were changed from one machine to another. The judges sat in the orchestra too far away from the booth to know what was going on in the booth. The result was that no one could definitely tell which lens was illuminating the one field or the other. There were slight differences in the illumination but they were caused evidently by accidental conditions and did not at all depend upon the lenses. The experiment was repeated a number of times with no differing results. This test is, of course, very coarse when compared with the methods used by Mr. Richardson and Mr. Burrows, but seemed at that time sufficient to convince me that the amount of illumination possibly gained was not worth while the additional complication of the projection lens. As soon as I have a chance I shall repeat such test and see whether I cannot make Mr. Richardson's conclusions agree with a practical test in the theater.

CONTRIBUTED DISCUSSION BY DR. STORY

If you will allow an outsider to add to this discussion, I should like to suggest that as in so many arguments one difference between the paper and the opposition it mentions is simply a matter of terms. In the paper the word "beam" and "ray" are both used to denote the complete cone of light emerging from the condenser. Now in optics "ray" is used as a convenient expression for a light path of infinitely small cross section. A ray accordingly can never diverge any more than it can converge. To the theorist then to speak of the ray diverging from the point of maximum concentration is a misnomer.

On the other hand, the condition for the convergence of the entire beam issuing from the condenser is that the image of the source shall be smaller than the condenser or, in the case of a condenser having spherical aberration, not much larger. Or that where

$$D_s < \frac{D_c\,(d_s - F_c)}{F_c}$$

D_s is the diameter of the source, d_s the distance from the optical center of the condenser to the source, D_c the diameter of the condenser, and F_c its focal length. This condition is invariably met

with in practice. Beyond the point of maximum concentration this beam does diverge as the paper shows.

If the condenser has spherical aberration the rays through the center will image at, or as we say, "converge to," a point beyond the point of maximum concentration. At this imaging point of the central rays the rays through the outer part of the condenser have already converged to an image and now diverging form the boundary of the diverging beam. Thus we see that the beam is diverging beyond the point of maximum concentration, as the name of this point indicates, some of the rays are still converging.

This misunderstanding simply illustrates the necessity already pointed out in this meeting of care being exercised to use terms taken over from the older branches of optics in their previous meaning where this is possible.

The question as to whether the point of maximum concentration should be at the aperture plate or at the objective is a very different matter. To consider this we must advance but one theory and that amply proved experimentally. That theory is that the maximum light at any point from any source of uniform brilliancy through any opening has been obtained when the entire apparent area of that opening is covered by the source of its image. This, of course, leaves out of account losses due to the reflection from lens and mirror surfaces and absorption in their materials. This means that if at any point beyond the aperture plate every point of the film has a bright spot of the condenser behind it, at this point we have as much light through the film as is possible to obtain with a source of this intrinsic brilliancy. If this is true for every point on the objective lens, we are supplying to this lens all the light it can use, for each of its points has the maximum light available. If there are any points alongside the objective for which this condition obtains, then the lens is not using all the light the rest of the system is offering it. Let us be sure to remember, however, that the condition is that behind all points of the film there shall be an illuminated area.

If we consider a vertical section through a diagonal of the aperture plate and the center of the objective, and if we draw lines from the top and bottom of the objective opening to the bottom and top of the aperture respectively, and extend these lines in both directions, they obviously indicate the cone that must be filled with light in order to have our conditions of maximum brilliancy satisfied, and it does not in the least matter from the standpoint of quality of light through the objective how far from the aperture plate the source or condenser is placed. The only requirement is that the base of this cone as seen from all points of the objective shall have at every point the brilliancy of the source. If we could use a source large enough to cover this base at any point beyond the aperture, no combination of mirrors and lenses with this source would give us one iota more light on the screen. By the use of a condenser, however, we can cut down the necessary size of our source and in so doing decrease our power consumption.

The object of the condenser is then simply to make the source seem larger, so large in fact for best illumination that it covers the

entire base of this cone and by just as much as this magnification of the source fails to cover the cone by that same proportion does our light through the objective and therefore on the screen fall below the amount possible with the illuminant aperture and objective used. Now to cover this cone we must have certain conditions fulfilled. In the first place, it is obvious the condenser must be as large as the cone at the point at which the condenser is placed, and that any area of the condenser outside this cone is entirely useless. In the second place, and here comes the point in the paper to which all this serves but as preamble, the entire area of the condenser seen through the aperture from every point of the objective opening must appear illuminated, that is, every straight line on which points of the objective and points of the aperture both lie is an actual path of light.

If we consider a corrected condenser it is easily seen that this condition is fulfilled, if, and only if, some section of the cone in front of the aperture or beyond the objective shall be entirely covered by an image of the source. Between the aperture and objective the image must cover the area indicated by lines diagonal on our section from the top and bottom of the objective opening to the top and bottom of the aperture opening respectively. We see then that any position from the condenser to the screen, of the image of the source by the condenser is capable of giving the maximum light possible with the objective, provided only the cone is completely filled. For the best position, therefore, of the image we must look to some other factor than simply the maximum possible illumination, always keeping in mind, however, the two requirements already found.

The natural direction to look is toward efficiency. At which one of all these image positions can we get this maximum quantity of light through the objective with the least power consumption—that is, the smallest area to be illuminated to the intrinsic brilliancy determined by the nature of the illuminant? We see at once that we shall need a smaller area of source if we so choose the focal length of our condenser that the image will fall at the aperture plate than at any position in front of this with a given minimum distance between source and condenser—generally determined by practical limitations of temperature. For positions of the image beyond the aperture plate we easily see that if D_o is the effective diameter of the objective, F_o its equivalent focus, D_a the diameter (or diagonal) of the aperture and D_A its distance from the optical center of the condenser, the necessary source area is still a minimum with the image at the aperture plate unless

$$D_o < \left(1+\frac{F_o}{d_A}\right)D_A$$

in which case we can use a smaller source with it focused in the objective than would be necessary for maximum illumination if the image were focused on the aperture. This condition is usually fulfilled in lantern slide but not in motion picture projection.

As for the distance from the condenser to the aperture it may be selected at will, subject of course to the condition that the

condenser must cover the entire cone, or the smallest diameter allowable is

$$D_C = D_A + D_A\left(\frac{D_O + D_A}{F_O}\right)$$

Then with everything else kept constant we can get as large a D_A as we choose if we build a condenser large enough and of the right focal length to match it.

In the case of a lens with spherical aberration we have no image proper, but, as has been said, a point of maximum concentration lying in front of the best image attainable. Accordingly if we put this point of maximum concentration in or beyond the objective, not only will the aperture plate in ordinary practice cut off the light from the outer portions of the condenser, but since the remaining central rays are brought to a focus beyond the objective, even the central part will require a larger source area to fill the whole cone than it would if the image were brought nearer the condenser. Thus we are using a larger condenser and larger source than we need. Thus we see that if we put the point of maximum concentration in or beyond the objective, spherical aberration but advances the image formed by the effective central rays further along the path and so increases the area of source required.

Now let us see whether there are practical difficulties in filling the cone. Let us consider the two sources in most common use.

First the arc. The intense heat of the arc means the condenser cannot be put close to it with safety. This means that to get an image to cover the section of the cone even at the aperture, it must be far from the condenser, which means a large condenser, or the arc must itself be large, which means high amperage. In practice it has been found impossible to meet these conditions. Accordingly, to get uniformity of illumination over the whole film, a relatively long focus condenser is generally used of a size considerably smaller than sufficient to cover the cone. (Fig. 1 of the paper). The great intrinsic brilliancy is relied upon to make up for the inefficiency of the optical system. In this case with an objective of average size the aperture is certainly the place for the image. Spherical aberration will necessitate the aperture near the point of maximum concentration for uniform illumination as the paper points out.

Second, the incandescent filament. This has a relatively low average brilliancy, but because of its size and the fact that it can be placed close to the condenser without excessive breakage the optical system used with it can be much more efficient. In fact with an energy dissipation but a fraction of the arc, the entire area of the largest objectives can be utilized. The power necessary for maximum illumination could be still further cut down, as has been shown, if the source could be focused on the aperture. This is impractical because with any incandescent lamp now in use the illumination over the entire filament area is not uniform. If this variegated pattern were focused on the film the objective would throw on the screen a picture not only of the film but of the filament as well. In order to avoid this it is necessary to focus the source at some other place, and as we have seen above, the most efficient region is between the aperture and the objective—the further we go from the aperture,

the more uniformly it is possible to light the screen and the larger must be the source.

If we consider the cones of light bounded by the lines drawn from a point on the edge of the condenser to the top and bottom of the source and of the image (considered in the objective) we can readily see that, due to excessive bending caused by spherical aberration, the emerging cone will not now just fail to pass the aperture, but that part of the light will go through the aperture and of course fail to strike the objective. We shall then get the same illumination no matter how much we increase the spherical aberration until it reaches the point where the top of the cone passes through the aperture opening. Any further aberration will mean a loss of light at the edges of the screen. Of course, this allowable angular deflection due to aberration, depends on the size of the source, its distance from the condenser and the size of the condenser. Spherical aberration then decreases the light lost at the aperture plate and spreads this light out in a hollow cone outside the objective aperture. Thus whereas without spherical aberration this light was lost on the aperture plate, with spherical aberration it is lost on the objective mounting. It should be noted that increasing the size of the objective to include this light, though it would undoubtedly put more light on the screen, would put half as much additional light at the edges of the picture as at the center and we should have an un-uniform lighting similar to that obtained when the spherical aberration exceeds the amount indicated above. The only disadvantage of a little spherical aberration is the heating of the film by the passage through it of light the objective cannot use. There is a slight advantage due to the blurring of the filament image allowing it to be brought closer to the aperture without appreciable unevenness of illumination and accordingly reducing the area of the source required. And right here let me say that when we blame one part of the optical train for "wasting light," as we call it, we must be careful to see that the saving of the light by this will not merely necessarily transfer the "waste" to another place.

We see then that the only advantage in practice in putting the image of the source or, in case of a condenser having spherical aberration, the point of maximum concentration at any other place than the aperture is to avoid an unequal light distribution rather than to get a greater total amount of light on the screen or to save energy.

In closing a discussion already entirely too long, I should like to say just a word of caution on two points.

First that we be extremely careful in the use of the term "point source" as the assumption of such a source is sure to be confusing, if not actually dangerous to the truth of the conclusions we draw. There is no source of light now in use for projection purposes on the appreciable size of which the calculation of the optical train and its arrangement in the projector do not depend.

The second point I wish to make is that we should be sure that when we say "aperture" or "diameter" of a lens, be it compound or simple, we mean effective opening, that is, the opening of an equivalent simple lens situated at the optical center of the combi-

nation considered. It seems to me that the paper in urging the adoption of what it calls a short "back focus" is perhaps a little confusing on this point. Certain it is that with the small field and large aperture usually used, if the first lens of the combination were put close to the film, this lens might be made smaller than the others, but this certainly does not mean—as the paper seems to imply—that with this arrangement we can then use a small front lens (and so avoid shutter difficulties) and get the same picture on the screen—for it simply cannot be done.

Putting the rear combination nearer the aperture means, other things being equal, taking the front combination further from the aperture if the optical center, and so the focal length, of the objective is to remain fixed. This will mean that, though the first combination does bend the rays into a less rapidly diverging beam, the front combination being further away must be the same size as before to take in the whole of this beam. We may put the rear combination close to the aperture and so make it smaller, but the front lens can be no smaller than it would have to be were both combinations of the same size, as at present. The small rear combination may possibly give a cheaper lens; it will certainly not give a more efficient one. In fact, if this change involves the introduction into the lens of a third combination, as the paper suggests, and if there is a 10% additional reflection due to these additional surfaces, we shall have 10% less light on the screen. There are but two things that determine the size of a light cone a lens will take—the focal length and the effective aperture under the conditions of projection. The efficiency of transmission, which depends on the design of the lens, determines the percentage of the light actually falling on the lens that reaches the screen. This then is of equal importance with the aperture and a 10% loss here is equivalent to a loss of 10% of the cone.

In motion picture practice the effective aperture is never appreciably larger than the opening of the front lens. With the same size picture then, as long as the rear combination does not diaphragm the cone of light, it makes no difference in the size of the cone of light the lens will take, where the rear combination is placed, and any movement of the condenser and consequent change in the cone of light can be handled by a short lens as readily as by a long one. The paper suggests that increase in objective size alone will not take care of a greater cone of light through the aperture plate, but that the rear combination of the objective must be close to the aperture. To this I cannot agree. Given the focal length of the objective the one and only thing that determines the size of cone that can be covered is, to my mind, the effective diameter of the objective, and we may leave the relative position of the combinations entirely to the lens designer.

Just one more word. The paper speaks of the difficulty of using a large objective with a shutter. This may be a difficulty with the present shutters, but it seems to me there can be no real objection to making a shutter large enough to operate with any objective that can possibly be built. Whatever the difficulty there is lies solely in the adapting of present machines to this larger shutter.

CONDENSER DESIGN AND SCREEN ILLUMINATION

By H. P. Gage

NOTE. The preparation of this treatise was prompted by a reading of Mr. Richardson's paper on "Some Phases of the Optical System."

The purpose of this article is to illustrate the desirability of suitable design in order to secure a proper balance between the different parts of the optical system of the motion picture projector and to attain maximum light efficiency. Also, there is described a simple and hitherto little used method of observing the operation of the optical system which enables one to determine easily and quickly whether or not the proper balance between the different optical parts of the system exists, and whether there are any parts of the mechanism which interfere with the light.

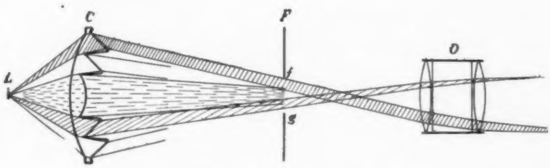


FIG. 1—Design of Corrugated Condenser
L One point of light source.
C Corrugated Condenser.
F (f–g) Aperture plate.
O Objective.

Motion picture projection depends upon mechanical devices for moving the film, and an optical system for projecting it. The optical system is not complete until the eye of the observer is considered, but in the present discussion it will answer to stop with the screen. The optical system for motion picture projection is illustrated in Fig. 4, the optical parts being enumerated and described below.

LIGHT SOURCE

The light source (L) may be any lamp having suitable brilliancy for the required projection. The lights most commonly used are the arc lamp and the special Mazda projection lamps. In the case of Mazda lamps it is usual to reinforce the lamp with a concentric spherical reflector (R). As the function of the reflector is to form an image of the filaments in the immediate neighborhood of the filaments themselves, the optical system is the same with the reflector as without it. The use of the reflector increases the light

thrown on the screen by about 70% when the reflector is clean and the bulb new. Figs. 7 and 8 show the glowing filament of Mazda lamps, with the spaces between the filaments illuminated by the images projected by a concentric spherical mirror.

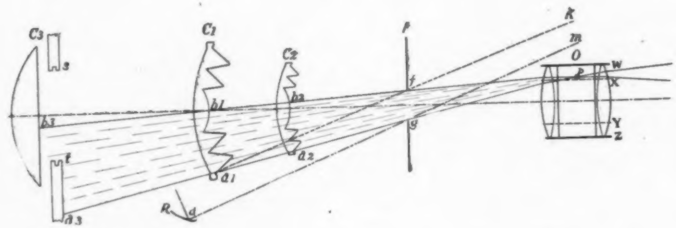


FIG. 2—Relation of the diameter and separation of the condenser to the diameter and focus of the objective

C_1 Large diameter corrugated condenser.
C_2 Small diameter corrugated condenser.
C_3 Front element of plano-convex condenser system.
s–t Opening in slide holder placed directly in front of the condenser. This removes considerable of the light from the condenser when so placed.
F (f–g) Aperture plate.
O Objective.
p A point in the objective.
b–f–p and a–g–p are the limiting rays of light which reach the point p after passing through the aperture plate.
A_1–f–k and d–g–m rays passing through the aperture which do not add to illumination as they cannot get through the objective.
W–Z Large diameter objective.
X–Y Small diameter objective which does not include the point p.

CONDENSER

The condenser (C) may consist of a pair of plano-convex lenses, of a meniscus lens combined with a double convex lens, or of a single corrugated lens of the general design illustrated in the accompanying figures. The function of the condenser is to collect the diverging light rays emanating from the light source and to concentrate them upon the picture to be projected so as to produce an intense but evenly distributed illumination.

APERTURE

The aperture is an opening in a metal plate 29/32 in. wide and three-fourths as high used to limit the edges of the picture. In immediate contact with this aperture is the strip of film on which is printed the picture to be projected. The location of the aperture plate and film is designated by F. It is generally assumed that both the picture on the film and the edges of the aperture are in focus at the same time.

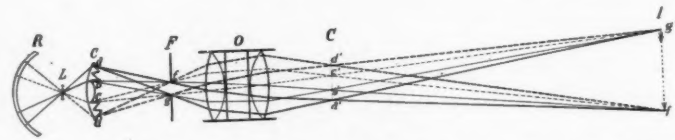


FIG. 3—Image formation of a single point on the film. All parts are drawn to scale

F Aperture plate

f Point on Film (located at extreme edge).

O Objective. The entire diameter of the objective is used to form the image of f.

f' Image of f.

C Condenser.

a–b Limits of condenser useful in illuminating f.

L Light source.

m–n Limits of light source useful in illuminating f. If the eye is placed at the point f' the entire area of the objective will appear filled with light.

FIG. 4—Image formation of condenser surface

F (f–g) Film located at the aperture is imaged by the objective O at the screen at I as f'g'.

C (a–b–c–d) Condenser, is imaged by the objective at C' (a'–b'–c'–d').

L Light source.

R Reflector.

O Objective. The objective is drawn of absurdly large diameter to better illustrate the formation of the condenser image. All other parts are drawn to scale.

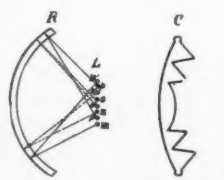


FIG. 5

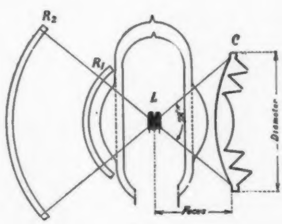


FIG. 6

FIG. 5—The use of a concave spherical mirror to form images of the filaments in the spaces between the filaments

R Concave spherical reflector.

L Light source. The filaments m, n, o, p, are imaged at m' n' o' p'.

FIG. 6. Necessary clearance between lamp filament and condenser, angle of light received by the condenser and necessary angle of the reflector

L Light source, filament of lamp.

R^1 Small reflector.

R^2 Large reflector.

The lines around the filament are to represent the glass bulbs: T–16, T–20, and GT–28.

OBJECTIVE

The objective is made up of several lenses of suitable design which are assembled in a single mount. The design of the objective must be such that it has all of the desirable qualities to be found in photographic objectives. These qualities are so fully and frequently described in photographic literature that it is unnecessary to go further into their enumeration. In the most elementary text books on Physics are to be found discussions of the "simple thin lens." Such a lens cannot be made of a single piece of glass on account of countless "aberrations," but if such a "simple thin lens" could be made it would have all the properties required of the photographic or projection objective. In fact, in theoretical calculations which involve the objective we can substitute for it an imaginary simple thin lens which has a suitable focus, position and diameter. Let us leave it to the skilled optician to design and construct this objective for us, allowing him to use any varieties of glass, any curvature and separation of the elements, any type of objective which he may deem most suitable for the purpose, but let us caution him to use no more glass-air surfaces than are necessary, for at each surface where the glass and air come in contact there is a loss of about 5%, *i.e.*, a loss of 10% for each lens or cemented doublet; and let us require him to make the diameter of all lenses as large as he can in order that the objective may transmit the greatest possible amount of light. When the optician's work is completed let him tell us what the equivalent focus of the objective is, also its equivalent diameter (if that should differ from the diameter of its lenses) and we will then put in our drawing a simple theoretical lens having this focus and diameter and all our calculations will come out exactly as if we had traced each ray through the complicated lens system of the actual objective.

The purpose of the objective is to form a real image I, (f'g', Fig. 4) of the film F, (f, g,) upon the screen. In addition, the objective forms images of everything on one side of it at some place upon the other side of it. For example an image of the condenser C, (a, b, c, d,) is formed by the objective O at the place C' (a' b' c' d'). If the condenser C is located too close to the film its image will lie near the film image, as in the case of stereopticon slides, and if the surface of the condenser is cracked this condenser image C' will lie so close to the picture image I, that disturbing shadows are seen. In ordinary motion picture projection as here illustrated there is no danger of imperfections or condenser rings appearing on the screen.

Dimensions of Elements

OBJECTIVE

The equivalent focus of the objective is fixed by the size of the picture which it is desired to project and the distance to the screen (throw). The necessary focus can be found in any of the

numerous tables which are published on the subject. For a given theater, the focus is fixed by the conditions in that theater.

The diameter of the objective should be as large as can be obtained in order to utilize as much of the light passing through the aperture as is possible. When using the arc lamp as an illuminant, experience has shown that it is much easier to obtain an even screen illumination free from shadows and dark corners with a large than with a small objective. With the incandescent lamp the entire area of the objective is utilized to image each point of the picture, hence a large objective will give a more brilliantly illuminated screen than will a small one. See Figs. 10 and 11. Objectives are regularly manufactured with free diameter as great as $2\frac{7}{16}''$ and equivalent foci of $5.62''$ or greater. The objectives studied in the preparation of this article had an equivalent focus of $5.62''$. One had a free diameter of $2\frac{7}{16}''$ and the other $1\frac{5}{8}''$, *i.e.*, photographically speaking they had a speed of f/2.3 and f/3.6 respectively. It is possible to make an objective of even greater speed than this and at least one has been made up on special order with a speed of as great as f/2.0 which worked successfully with motion pictures. The head of some machines will not take these large sized objectives. This is unfortunate as it imposes a limitation upon such machines which will be increasingly felt in the future. In general, the largest commercial objectives of $5\frac{3}{4}''$ focus or greater have a free diameter of $2\frac{1}{2}''$ and those of shorter focus have a smaller diameter, so that the ratio between diameter and focus remains about the same.

With the exception of Fig. 4, in which the diameter of the objective is drawn absurdly large in order to make clear the formation of the image of the condenser, the different optical parts are drawn correctly to scale, and the objective is drawn with $5\frac{1}{2}''$ equivalent focus, $2\frac{7}{16}''$ free diameter corresponding to the photographs.

APERTURE

The aperture opening (f, g) shown in the drawings is the standard width of $29/32''$.

CONDENSER

In a given projection apparatus the dimensions of the objective and the aperture are fixed, and the condenser and light source are the elements which must be varied in order to secure efficiency. While the condenser to be described was developed to meet the needs of the incandescent lamp the optical reasoning applies equally well to any light source.

As illustrated in Fig. 6 the clearance between the surface of the condenser and the filament L must be sufficient to allow room for the bulb. The greatest angle of light receivable by this type of condenser for efficient operation is 78° or 80°, and the reflector obviously must cover at least as great an angle as the condenser. The larger diameter reflector (R_2) is preferred as it is farther away and does not get as hot as does the smaller one. For the largest

bulb shown G-T-28 a condenser $4\frac{7}{16}''$ in diameter with $2\frac{1}{2}''$ focus answers well. The smaller and more compact condensers give the same efficiency but as they afford less space between condenser and aperture plate (Fig. 2) they are not much used for professional projection.

The general elements in the design of the corrugated condenser are illustrated in Fig. 1. This illustrates the method of bending the light originating from a single point of the light source. The fundamental principles involved in screen illumination are: first, the illumination must be even, without streaks or shadows, and second, that it must be sufficiently intense. The light from each point of the light source is collected in such a way that it evenly illuminates the entire aperture. This is necessary with the incan-

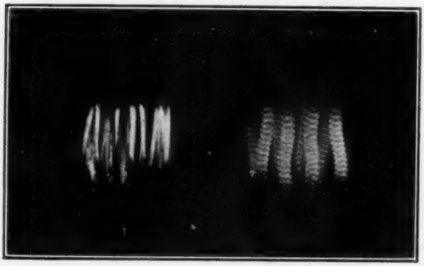


FIG. 7 FIG. 8

FIG. 7 (Left)—Filament of ordinary stereopticon lamp backed by spherical reflector.

FIG. 8 (Right)—Filament of special monoplane filament projection Mazda lamp backed by spherical reflector. After burning for some time the filaments bend slightly so that there are small dark places between the filaments even when using the reflector.

descent lamp, as it is made up of a number of sharply defined streaks of light separated by dark spaces. If the condenser design or adjustment is such that the illumination from a single point is non-uniform then the illumination from an incandescent lamp will be streaked.

The relation between the diameter and distance of the condenser from the aperture for maximum efficiency is fixed once the diameter and focus of the objective are determined upon. For a given point P in the objective to be effective in transmitting light to the screen from all points of the picture between f and g, Fig. 2, it must receive light between the points a1 and b1 of the larger condenser or between a2 and b2 of the smaller one. If the condenser is located too far away as in the case of C3 (12″ separation between condenser and aperture) and especially if the condenser is diaphragmed down by the slide holder permanently fastened in front of it, as is now too often the case, it is evident that the objective is not functioning to full efficiency. (See Fig. 10 c and d.)

Light bent too sharply as in the case of the ray a_1fk is not useful nor would light such as d–g–m collected by an extra ring or reflector outside the condenser serve any useful purpose. Such light, while striking the film, would unnecessarily heat it, and, entirely missing the objective, would never reach the screen. Thus is determined the proper proportion between condenser and objective.

POSITION OF THE SHUTTER

There has been considerable discussion as to the proper position of the shutter. When the shutter is located in front of the objective (outside shutter) it is desirable to place it in the narrowest part of the beam. With the arc lamp as an illuminant, there is a restriction in the beam at the position of the condenser image, similar to C' in Fig. 4 and this is the preferable position for the

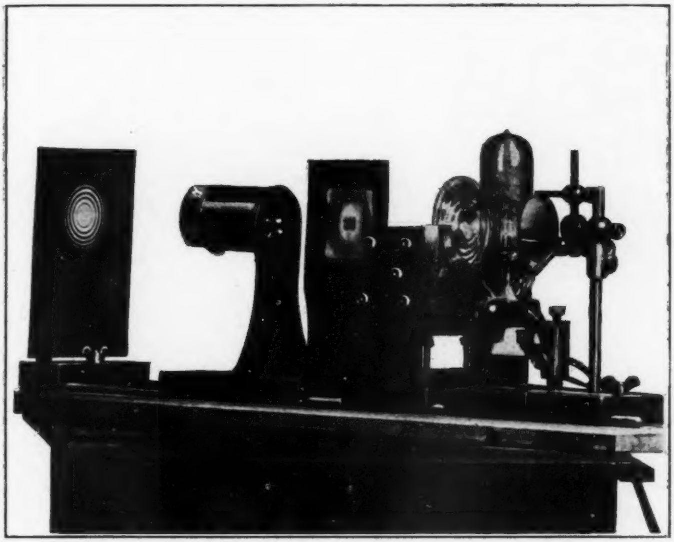


FIG. 9—Apparatus used in testing condensers. This shows the lamp, reflector, condenser, aperture, large objective, and screen placed at the aerial image of the condenser. The dark rings shown in this image do not appear on a screen placed at the usual distance for viewing the pictures.

shutter. With the incandescent lamp, however, owing to the closeness of the condenser to the objective, its image is larger than the objective, and the narrowest part of the beam is immediately in front of the objective. This is also illustrated in Fig. 3 where the extreme edge rays of light diverge from the objective as does the lower ray in the illustration.

Observation of Optical System

The method of observing the optical system to determine whether the necessary conditions are fulfilled to secure maximum efficiency is illustrated in Fig. 3 and the photographs, Figs. 10–12. In Fig. 3 the point f, located at the edge of the aperture, is so illumi-

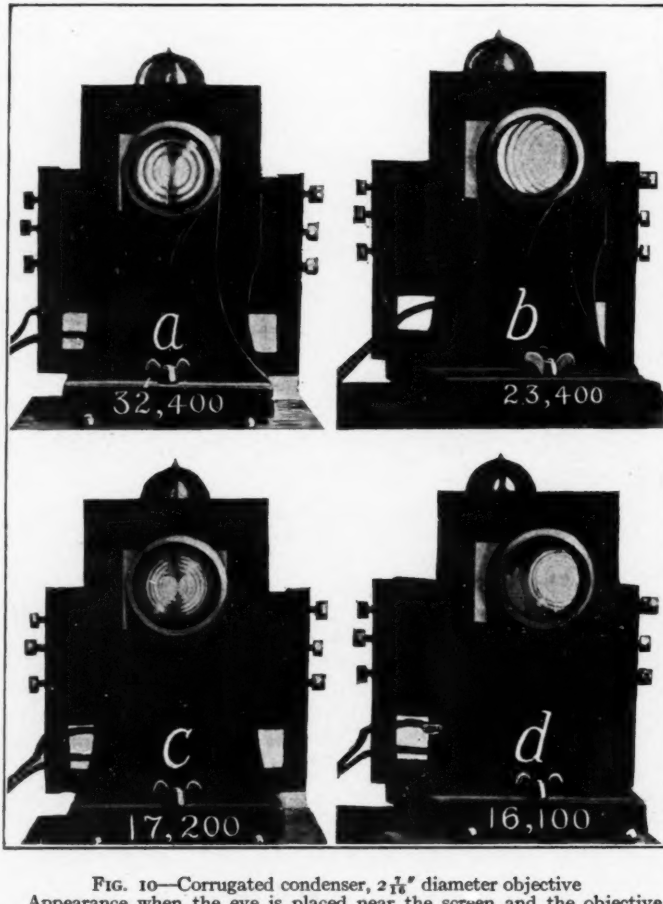


FIG. 10—Corrugated condenser, $2\frac{7}{16}''$ diameter objective

Appearance when the eye is placed near the screen and the objective is observed through dark glasses. The figures represent the relative intensity of the light coming through the objective in the direction being observed.

a. Center of picture, 6½ separation between the condenser and the aperture.
b. Edge of picture, 6½" separation.
c. Center of picture, 12" separation.
d. Edge of picture, 12" separation.

nated that the light rays spreading out from it diverge by just a sufficient amount to completely fill the objective with light. These rays are again converged by the objective to form the image f' at the screen. As the drawing illustrates it is evident that if the light rays diverged over a wider angle some light would be lost by missing the objective, while if the light diverged a less amount, the entire area of the objective would not be functioning.

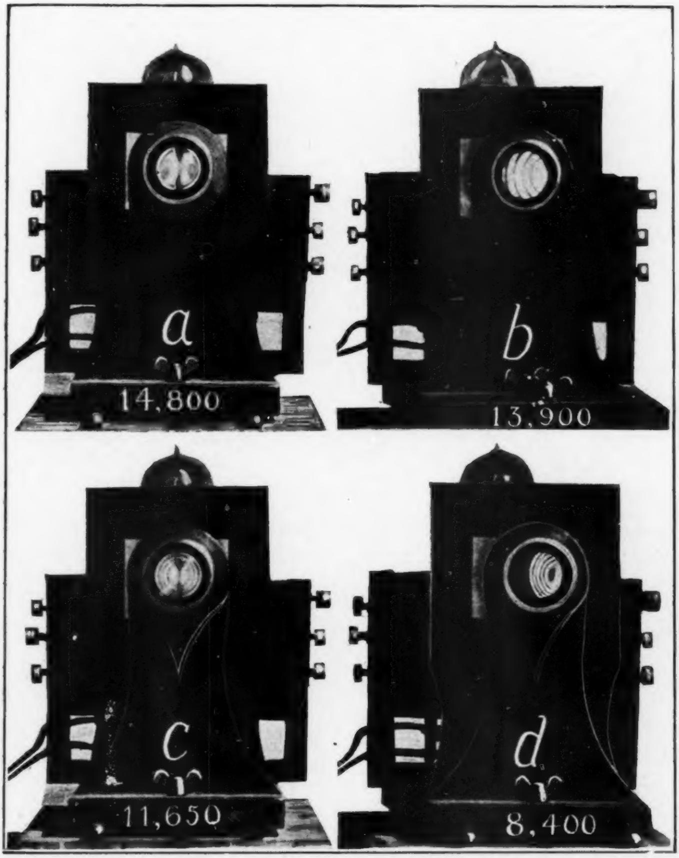


FIG. 11—Corrugated Condenser, 1⅝" diameter objective

a 6½" separation between the condenser and the aperture plate, from the center of the picture.

b 6½" separation, edge of picture.

c 12" separation, center.

d 12" separation, edge.

If now the eye is placed near the screen and looks back at the objective one sees a bright spot of light which may or may not fill the entire area of the objective. In order to do this with the arc or incandescent lamp burning at full brilliancy it is necessary to use either smoked glasses or to place a piece of heavily smoked glass between the light and the condenser or just in front of the condenser. The last position is preferable as it enables the observer to obtain a general view of the apparatus at the same time that the size of the light spot is observed. The result of such observations is shown in Figs. 10–12.

The apparatus used in the experiments here described is illustrated in Fig. 9. The different parts are the same as shown diagrammatically in Fig. 4 and consist of an incandescent lamp backed by a spherical reflector. The condenser serves to concentrate the light from the lamp upon a standard aperture. The objective serves to form a real image of a picture located at the plane of the aperture upon a screen in front of the apparatus. In the apparatus as illustrated a movable screen has been placed in the position occupied by the condenser image. With this set-up, which is used in testing all condensers, it becomes readily apparent that if the condenser contains an optical defect so that light from some portion of it does not pass through both the aperture and the objective the image will show a shadow at this point. Condensers which do not show all of the rings properly functioning are eliminated.

The tests illustrated in Figs. 10 to 12 were made by setting a camera with a telephoto objective of 50″ equivalent focus (x8) about 20 ft. in front of the apparatus. Two exposures were necessary, a 5-minute exposure to show the general outlines of the apparatus and an extremely short exposure to show the light spot coming through the objective. In Figs. 10 and 12 is illustrated the large objective with $2\frac{7}{16}''$ free opening and in Fig. 11 is shown the smaller objective $1\frac{5}{8}''$ free opening. Both are marked $5\frac{1}{2}''$ equivalent focus, and are supposed to be identical except in diameter. Figs. 10a and 11a show the appearance with the camera objective in the direct axis of the beam, that is, located in the position of the exact center of the picture. The separation between the condenser and the aperture is $6\frac{1}{2}''$ as is called for in the theoretical design for this combination illustrated in Figs. 1 and 2. Note that in the cases of both 10a and 11a the entire area of the objective is filled with light, and hence both objectives are contributing as much light to the center of the picture as they possibly can but that on account of its greater area, the larger objective is able to contribute more light than the smaller one. In Figs. 10b and 11b the same separation is used, but the camera was so placed that it was at the extreme edge of the picture, *i.e.*, if it were even one inch farther towards the side, no light from the lamp would reach it. This shows both the large and small objectives still completely filled with light.

If instead of using the corrugated condenser, as previously illustrated, it is desired to use the ordinary plano-convex condensers, a separation between the front of the condenser and the aperture plate of much more than the $6\frac{1}{2}''$ previously referred to is

required. With the incandescent projection lamp even illumination can hardly be secured with a less separation than 12", while for operation with an arc lamp, a separation of at least 16" is recommended and a separation of as great as 22" seems to be required for low amperages. The result of employing two 7½" plano-convex condenser lenses with the incandescent lamp, and the large objective, using a separation of 12" is shown in Fig. 12. The dark spaces in the condenser image are the result of the dark spaces between the filaments of the lamp. Note that the objective is

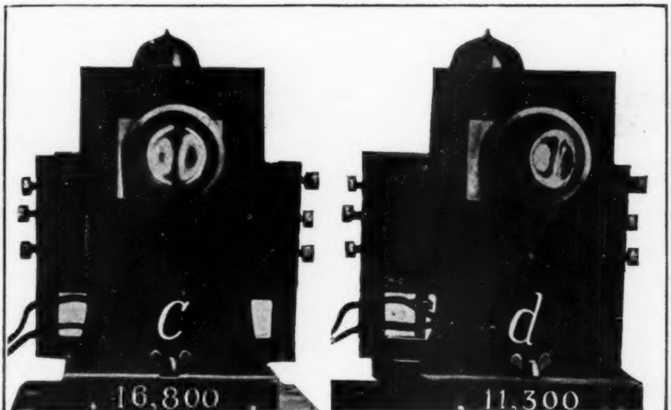


FIG. 12—Plano-convex condenser system, 7½" focus lenses, 2 7/16" diameter objective

c 12" separation between the surface of the front condenser lens and the aperture plate. From the center of the picture.

d 12" separation, edge.

not entirely filled with light even when looking directly into it (Fig. 12c), and when looking at it from the edge of the picture the space between the edge of the condenser and the objective is increased and part of the area of the condenser is cut off. It is entirely possible to employ the corrugated condenser with a separation of 12" and get practically the same results as with the plano-convex condenser system if this greater separation is desired. The result in the case of the large objective is shown in Fig. 10c and d and in the case of the small objective in Fig. 11c and d.

The comparison between different illumination systems can be illustrated photographically, but the engineering data for discriminating between them are not complete until photometric measurements are made to determine the ability of each to illuminate the screen. It is often a difficult matter for the eye to discriminate illumination differences of 10% to 25%, but small

differences of this size are by no means insignificant when counting the cost as recorded at the meter. Illumination tests were made by substituting the test plate of a portable photometer for the camera objective used in taking the photographs illustrating this article. In making such photometric tests the actual screen illumination obtained with a given system depends upon so many elements, such as the equivalent focus of the objective, magnification, screen distance, density of film exhibited, exact shutter design, individual lamp used, age and condition of lamp, reflector, and line voltage at the time of making measurements, that it is hardly within the scope of the present paper to give detailed measurements of actual screen illuminations, but there are recorded comparative measurements of each system in Figs. 10-12 and in table 1.

Table I

SCREEN ILLUMINATION WITH DIFFERENT CONDENSING SYSTEMS FOR LARGE AND SMALL DIAMETER OBJECTIVES

	Separation between Condenser and Aperture Plate	Two Plano-convex Condenser Lenses $4\frac{7}{16}''$ diameter $7\frac{1}{2}''$ focus		Corning Corrugated Condenser $4\frac{7}{16}''$ diameter $2\frac{1}{2}'' \times 6\frac{1}{2}''$ foci	
		Center	Edge	Center	Edge
Large Objective	$6\frac{1}{2}''$	Streaked	Streaked	32,400	23,400
$2\frac{7}{16}''$ Diameter, $5\frac{1}{2}''$ Focus	$12''$	16,800	11,300	17,200	16,100
Small Objective	$6\frac{1}{2}''$	Streaked	Streaked	14,800	13,900
$1\frac{5}{8}''$ Diameter, $5\frac{1}{2}''$ Focus	$12''$	12,200	9,300	11,650	8,400

Examination of Table 1 shows us that if the plano-convex condenser system is used with a $6\frac{1}{2}''$ separation it is impossible to get an evenly illuminated field with either objective. With a $12''$ separation a fairly even field may be obtained, free from streaks, and the intensity at the edge of the picture is at least 70% of that at its center. The intensity is substantially the same as with the corrugated condenser for the same separation. To definitely determine whether with this separation there is any consistent difference between the plano-convex and the corrugated systems would require a much more extended series of measurements than was possible to make at the present time. The table does, however, show definitely two things.

First, with every condenser system a much higher screen illumination is obtained with the large than with the small diameter objective.

Second, with a given objective a much higher illumination results with the corrugated condenser at $6\frac{1}{2}''$ separation than can be obtained with either condenser at $12''$ separation. The fact that owing to its design the corrugated condenser gives an even screen illumination at $6\frac{1}{2}''$ separation, whereas the plano-convex condenser gives a decidedly uneven or streaked illumination with a separation substantially less than $12''$, points to the conclusion that for highest illumination efficiency the corrugated condenser used at $6\frac{1}{2}''$ separation is the most desirable condenser to use in connection with the Mazda projection lamp.

Conclusions

From the foregoing experiments as illustrated by diagrams, measurements and photographs it is apparent when using the incandescent lamp as an illuminant that:

First, a relatively large diameter objective is to be preferred.

Second, a short separation between the condenser and aperture plate, suited of course to the diameter and focus of the objective, is advantageous.

Third, the great advantage of the corrugated condenser is that an even screen illumination can be secured with a shorter separation between the condenser and the aperture than is possible with the plano-convex condenser system, thereby securing the greatest possible brightness of the picture.

Fourth, to get the greatest screen illumination when using the incandescent lamp the combination of all of the optical elements working at their greatest efficiency is required, including good quality reflector, proper adjustment, large diameter objective, and corrugated condenser used at the separation of $6\frac{1}{2}''$ from the aperture plate for which it was designed.

ADDING COLOR TO MOTION

By William V. D. Kelley

Not long ago I ran across this very interesting statement by Dr. Foote:

"The fact is, we have kept on discovering and forgetting and then re-discovering, ever since man began to think."

I was not there when man began to think, so naturally I cannot verify this part of Dr. Foote's statement. I can testify, however, to the fact that in the field of natural color photography and color photography as applied to the motion picture, we have kept on discovering and forgetting and then re-discovering.

The records show that as far back as 1785 natural color photography was engaging the attention of men of science. Men discovered at that time; later, men forgot; and then men discovered again.

I have seen samples of work done by the "bleach-out" process which was first suggested in 1813 by A. Vogel.

In 1861 the modern theory of three-color photography came to be recognized, and during the succeeding forty-five years some progress was made, slow and halting to be sure, but nevertheless, progress, in developing processes for recording scenes in color.

In the year 1900, while I was residing in London, England, an American, Mr. Tripp, was demonstrating the McDonough process of color screen prints, and later in that same winter I attended a lecture and demonstration of the Sanger-Shepherd process at the Royal Photographic Society.

At that time I was connected with the American Mutoscope and Biograph Company, and, therefore, motion picture photography and the possible application of adding color to motion was intensely interesting to me.

All of the different forms of producing natural color pictures were well known at that time, for we had the Lippman process, which is based on the interference of light waves, the McDonough, which is additive and the Sanger-Shepherd, which is subtractive.

Mr. F. E. Ives was demonstrating his Kromscope, which is an additive process, while in our Mutoscope parlors we were showing in a penny slot machine, six views of subtractive photographs made by Gaumont.

The first motion picture films in natural colors to receive any degree of publicity were those of Smith in 1906, which were fathered by Urban of international fame, although private showings of similar films had been given some time previous to that.

The shortcomings of that process led men to see possibilities of applying the Sanger-Shepherd method to Kinemacolor negatives, and their results were promptly recorded in the British Patent Office. Some of these patents have nearly expired, but none has yet been reduced to a working basis and none has been shown publicly, to my knowledge.

So you see, in speaking on the subject of "Adding Color to

Motion," we have a certain background of discovering and forgetting and re-discovering which will not permit any one at the present time to say that adding color to motion is an entirely new science.

In the *British Journal of Photography*, December 6, 1912, Mr. H. Quentin, referring to screen plates says, "And thus it is that in screen plate color photography the chief merit consists not in inventing a screen, but in producing it commercially." In the making of Prizma pictures in natural colors, the industry with which I have been mainly identified for a number of years, our problem has been largely one of devising means and developing processes that would make motion pictures in natural colors commercially practicable.

In a report for the Society of Chemical Industry in 1916, Mr. B. V. Storr, of the Ilford Company, London, said, "A number of patents have been published both for multicolor screens and for various details in the production of positives. In the latter, apart from the mechanical difficulties of registration, the chief problem appears to be to get a method of coloring which will give a uniform tone throughout the length of film."

We had considered for some time that other steps were of more importance in the making of Prizma films, but we found at last that our main stumbling block in making the present product finally proved to be the matter of coloring.

The successful making of small pieces of film by the known methods used in photography for toning or the patented descriptions of coloring methods were found to be impracticable when applied to the commercial handling of films in long lengths, so it became necessary to work out a new method and means for coloring. This we successfully accomplished.

Our problem contained several elements that required the development of new processes in order to accomplish the result of co oring long lengths of film commercially. The film may be 200 feet long, in which length, as you know, there are 3200 separate color transparencies, all very much alike with the exception of those parts showing the steps of movement. To make each picture exactly like the next and to duplicate the copies so that they are all alike, was the problem that had not been satisfactorily solved before.

In letterpress printing, if the copies vary, no damage is done, as one seldom sees many prints together for comparison and the poor ones are discarded.

With motion pictures there is not so much chance for discarding individual pictures, for if we did the film would consist mostly of patches. This problem was overcome, and film has been produced in quantity, so that each individual image-bearing area is substantially complete in colors which may be seen by holding the film in the hand.

COLOR RENDITION

I read that, "It is not possible for anyone to explain how or why we see colors, and probably it never will be." We have our theories

which stand up well against practice, but are unable absolutely to check back and prove them out. A good portion of the audience that view natural color pictures see colors at variance with what we term normal vision. Others attempt to judge colors from their own conception of what they should be. For example, the color of the waters of the Pacific Ocean varies from that of the Atlantic Ocean, and to one who has not noted this difference by personal visit, the color rendering may be judged to be unsatisfactory. Don't be hasty in forming your judgment as to the color correctness of a picture—your neighbor may be seeing it differently from you. I have seen a picture projected in which the color of certain flags appeared as orange to me, while to my associate they were pink.

THE EXHIBITORS

In the "British Journal of Photography" of February 1, 1918, on page 8 of the Supplement, there is added to an otherwise more or less correct statement, the following:

"Altogether, it does not look as though the commercial prospects for additive processes of color cinematography are very encouraging. *We have still to wait for the ideal color film which can be bought all complete by the yard and inserted for projection into the standard cinematograph lantern.*"

On December 28, 1918, Prizma began releasing weekly natural color films which can be "bought all complete by the yard and inserted for projection into the standard cinematograph lantern."

From the exhibitor's standpoint that is the big accomplishment; for all previous natural color films required either high projection speed, so high that such films only have one-third their normal life, or an attachment, or a complete new projector. Nearly all of these forms, in actual practice, required the attention of a special trained operator from the home office, or what is just as troublesome, a course of instruction to the theater operator, before the films could be left with safety and assurance of successful shows.

THE COLOR WORKERS

For the information of those that like the "ins and outs" of the process employed will say:—

The negatives are made through two sets of complementary colors, or as we usually say, four colors.

The four color values are dyed in two colors. That is to say, the reds and oranges are dyed a red-orange color, while the greens and green-blues are dyed a color complementary to the red-orange colors used.

In many subjects when the film is examined in the hand, there is a noticeable difference in alternating images, in which case one will favor the green-blue, and the succeeding image will favor green. These blend without pronounced flicker on projecting at the customary projection speed.

The projection is on the additive principle of mixing lights while the production of the image is accomplished by the subtractive principle.

Registration of two images on the same area, done continuously in long lengths and consistently accurate, is had to 1/10,000 of an inch. This, in spite of the fact that developed negative shrinks to an average of $\frac{1}{16}$ of an inch in each foot, sometimes as much as $\frac{1}{8}$ of an inch, while there is a corresponding shrinkage laterally. The fresh positive at the time of printing is still of standard width and length, and consequently of different length and width as compared with the negative.

The above paragraphs place the matter before you in brief language. Rather than enlarge on each item by tearing to pieces and analyzing each step, I have prepared a film that demonstrates most of the steps.

So that you will know what to look for I will add that we are using a projector that permits us to stop and view the films as we would lantern slides. You will, therefore, see the difference between additive and subtractive colors in pictures and not in words, for has not someone said "that a reel of pictures will tell more than 300 pages of printed matter and in a much shorter time." You will see the nature of the colored images when separated into single colors. The results of incorrect coloring. What registration means. The accuracy of the color rendering for we have the pictures on the curtain and the fabrics that were photographed in our hands. A duplicate of the original negative will be seen, which shows the color values but which of itself is devoid of color.

ATTACHMENTS TO PROFESSIONAL CINEMATOGRAPHIC CAMERAS

By Carl L. Gregory, F.R.P.S. and G. J. Badgley

It is almost as certain as death and taxes that no professional motion picture studio photographer is entirely satisfied with any model of camera that is manufactured to-day.

The Cinematographer does not consider that he is ready to take a picture until he has camouflaged his camera with more attachments than a Ford owner can buy for his "tin lizzy." This is not so strange when we stop to consider that very few of the professional cameras available to-day are equipped with more than one or two of the many devices which are required to obtain the varied effects that are to be seen in practically every motion picture production. With the exception of the American built Bell and Howell camera, nearly all of the better makes of motion picture boxes are, or rather were, manufactured in Europe, for with the exception of a limited number of Pathe's, this production was entirely cut off by the great war. It would not be fair to pass on, however, without referring to the fact that a great number of sporadic attempts have been made in this country to manufacture motion picture cameras, but for one reason or another, none of the attempts has been successful, if we accept as a criterion the verdict of a large percentage of professional cinematographers.

It is hardly fair to class a camera as being a professional studio camera unless it has held its ground day after day and month after month under the grinding routine of steady studio production. Such an arbitrary classification should not be regarded as detracting from the merits of certain types of cameras, which are yet in the process of evolution and have not as yet, for one reason or another, come into general use for studio production. A number of models of high merit have been exhibited, which would have been eagerly tried out in the studios, if a sufficient number of them had been placed on the market, so that they could have been given a fair trial. Doubtless, some of these excellent models, which have relapsed into a comatose condition during the restricted period of the war, will now be revived and receive a proper introduction in the Cinematographic world. It seems reasonable to prophecy that the Cine camera of the future will be sold with a number of standard attachments in much the same way as the sewing machine is sold with an equipment for producing all sorts of fancy frills, tucks, pleats and ruffles. In much the same way must the professional camera be provided with attachments for producing dissolved vignettes, fades, irises, etc. Foremost among these attachments is the one for producing dissolves. Formerly, all dissolving and fading was accomplished by means of the iris diaphragm. Producing a fade by means of the iris under certain conditions is very difficult, as very few iris diaphragms are constructed so that they will close completely.

In making a fade, it is necessary that the exposure be diminished from the maximum to zero in a uniform diminuendo; or, in producing what is styled a fade-in, commenced at zero and with a uniform crescendo developed to the maximum normal exposure. Under good lighting conditions, the arc of movement from the normal exposure opening to that of a completed enclosed iris is extremely small; so that a gradual decrease through this small arc is exceedingly difficult to accomplish in a uniform manner, especially as it is almost always complicated by the fact that the iris will not close completely and a complete fade-out can not be obtained. The general practice, where this complication arose, was to place the hand over the lens as soon as the iris was closed as far as it would go; thus ending it abruptly without accomplishing the final diminishing point. A dissolve, which is a fade-in superimposed upon a fade-out, would be farther complicated by the fact that, in many cases, a scene which dissolved into another might be taken under poor lighting conditions and be succeeded by one taken in strong light, so that the arc of movement used in producing the diminuendo in one might cover several times the angle of the arc of crescendo in the other. This leads to the conclusion that the only method of obtaining a uniform dissolve would be to gradually decrease the exposure time by gradually overlapping the sector blade of the shutter as it revolves; thereby gradually decreasing the exposure. A number of excellent mechanical devices for advancing the sector blade of the shutter have been perfected. They are of two classes; the manually operated and the automatic. The manually operated is self-explanatory, as it is manipulated by the hand, while the camera is in operation. The automatic type is operated by the movement of the camera itself being brought into action at the required moment by throwing in a clutch driven from some part of the camera mechanism. With the manually operated dissolve, the fade may be of any desired length, whereas with the automatic, only a certain pre-determined length of fade may be produced.

In the Shustek camera, the advancement of the sector blade is accomplished by a differential gear.

In the Kronik Brothers' Camera two sector blades are advanced simultaneously from each side of the shutter opening by means of a pin passing through two curved slots in the sector blade, and a straight slot in the covering blade, this pin being actuated by a yoke which is moved in and out by a sliding sleeve on the shutter arbor. Only a very few of either of these types of cameras have been manufactured. The most common device for closing the sector blade is that of a spirally actuated sleeve upon the shutter spindle. In the Badgley shutter, which has been installed in dozens of Pathe and other makes of professional cameras, the sector blade is attached to a sleeve on the shutter arbor, which is hollow. A rod sliding in the hollow arbor carries a pin extending out through a straight slot in the arbor and engaging a spiral slot in the sleeve. By thrusting this pin-carrying member in or out of the shutter shaft, the relative position of the sector blade to the shutter opening is changed. A worm and gear train which may be thrown in or out of engagement with the camera mechanism by means of a clutch

operates this thrust rod slowly in or out and simultaneously moves an indicator which shows how far this sector blade is open or closed.

In the Bell and Howell camera and in the Duplex printing machine a spirally actuated sleeve also closes the sector blade across the shutter opening in the manner just described except that the details of the mechanical design are somewhat different than those employed by Mr. Badgley.

In all of the automatic installations so far mentioned the length of dissolve is pre-determined, generally three or five feet, and cannot be changed. An automatic shutter dissolve, in which the length of dissolve can be altered at will, would be a desirable feature in a professional camera, providing that it be not too complicated.

Mr. Carl Akeley has invented a shutter of this type, which can be set at practically any length up to ten feet, but has not yet brought it out. The demand for an adjustable automatic shutter dissolve does not seem to be very insistent, as in most of the exceptional cases where the standard automatic dissolve is not of the required length, the automatic mechanism is not used and the dissolve is manually operated to the desired length.

After considering the dissolving shutter as being the most important feature to embody in a cinematographic camera for professional use, there are a number of other features which are so nearly of equal importance that we will not attempt to arrange them in order of their usefulness, but simply take them up one after the other as they occur to our mind.

Intimately concerned with the operation of the shutter and in fact all manipulation of the camera is the amount of film used. Most cameras, even of the cheapest variety, have some kind of crude counter for recording the film footage; but the word crude is used advisedly, as most of these counters which are found installed in the camera when purchased, are of the crudest kind. It is often necessary in trick work and vision or double exposure to know the exact footage and even the exact frame at which a double is to commence or end; so that it is only by means of an accurate counter, or a lot of unnecessary counting and calibration by the operator himself, that he can interpose his trick work in the exact place in the film where it should go. There are a number of very excellent revolution counters upon the market, which count accurately backward or forward and which indicate in large plain figures their results, that may be easily installed in a camera and in such a manner as to count either footage, crank turns, or frames, as may be desired. The counters manufactured by the Veeder Manufacturing Company of Hartford, Conn., may be taken as representative of the kind of instrument useful for this purpose. One of the double counters, in which one face gives the total and the other face a sub-total, the sub-total face of which may be readily set back to zero by means of a thumb-nut, is excellent for our purpose. It would be a comparatively simple matter for the manufacturer to change one of these counters so that the unit wheel could be divided into sixteen parts and thereby record each individual frame, allowing the other numbers to record the footage. The Bell and Howell people have made a counter of this type by

combining a wheel of their own divided into sixteen parts with a Veeder counter, but unfortunately, in attaching it to their camera, has rendered it worse than useless; first, by attaching it to the one turn spindle which prevents the use of the trick crank; second, in order to obtain a set-back feature, made it frictionally operated so that its record, on account of slippage, is more often inaccurate than correct.

The Eastman Company has inaugurated an innovation with their negative film, which to be of any use, practically necessitates the use of an accurate counter. This innovation consists of photographing on the perforation edge of every foot of negative film before shipping a consecutive footage number which is recorded on the box in which it is shipped so that we may have for example, a roll of film 400 feet long, upon the edge of which we have recorded the consecutive numbers from 437,000 to 437,400. If, then, we keep track of our scenes for the future information of the cutter and editor, it is necessary for us in exposing this film to keep an accurate footage record so that our recorded numbers for the scenes will exactly coincide with those given to the cutter for his information in making the first continuity and for keeping track of all of the scenes in the production throughout all of his operations with the same. If this system were followed out, a tremendous amount of labor would be saved in the cutting rooms, as it would not be necessary for the cutter to look through roll after roll of film to identify a certain scene, as he could merely refer to the assistant director's record and tell in an instant by looking at the record number on the edge of the film, whether he had the right piece of film or not. This system, is of course complicated by the high numbers required to avoid duplication, especially in studios where there are a number of directors working at the same time, as it would be possible for two different directors to have rolls of films carrying the same consecutive footage numbers or even possibly, though not probably, according to the law of chances, that the same consecutive numbers might occur twice in the negative rolls used in the same production. A much more simple method which, as far as we know, has not yet been used, would be that of a counter record which would be automatically photographed upon the edge of the film during the operation of the camera, so that each production might have its own designation symbol and consecutive footage number impressed at the side of every frame throughout the negative of which the assistant director would keep record as the scenes were taken for the information of those in charge of all cutting operations.

While many of the devices of trick photography—so called—are frowned upon by the modern director, the striving after artistic effects has more greatly strained the resources of the photographer than any of the visioning back devices that were formerly the stock in trade of the old-time director. Dual roles are still employed to exploit the versatility of our stars and results which once were called trick photography now masquerade under the more euphonious title of photographic effects. The modern, up-to-date photographer has probably more use for inside and outside mattes than he did during the era of trick photography, but he now employs

them with a delicacy and finesse unthought of a short period back. If he does double exposure now it must be so accurately done that there is no weave or shifting visible between the primary and secondary exposures. He goes in for beautiful cloud effects and color values, using color screens, Vignetting devices and panchromatic films. His exterior iris must be so adjustable that its last encircling dot in closing may vanish at any given point in the frame and with any desired degree of diffusion. He must be able to give soft focus effects, fading away into indefiniteness at the edges, and yet retaining in his principal objects at the center of the film a sufficient degree of clarity to avoid over-stepping that hazy boundary between a pleasing softness and an out and out fuzzy-wuzzyness. For these effects he requires inside and outside mattes, slotted lens hoods, round and square closing vignetting devices, with perhaps a half dozen irregular or odd shapes closing in odd geometrical forms in addition, to give him a pleasing variety from which to choose and, in addition, have his camera so built that these devices may be attached and employed without unnecessary delay. In the employment of inside mattes it is generally necessary that they come in as close proximity to the film as it is mechanically possible to place them without coming into actual contact with it. The inside matte, in contradistinction to the exterior matte, is employed where the lines of demarcation between the part matted out and the part photographed should be as sharply defined as possible. Where a double exposure joins two of these sharply defined lines of demarcation, the cutting of the mattes so that the two exposures may exactly coincide without over-lapping or leaving unexposed space between is a matter of extreme mechanical precision and the mattes themselves and the grooves in which they are held must be made with the greatest of care. Every operation connected with the use of inside mattes must be carried out with the greatest precision, for the slightest movement of the camera will instantly reveal their use where two or more mattes are used in making a composite picture, because such movement will throw the parts of the composite image out of register. It is probably for this reason that camera men avoid as much as possible the use of interior mattes because they reveal with deadly accuracy even the slightest defects in camera manipulation. There is also a use for interior mattes for diffused edge effects by using them in another groove or series of grooves at varying distances between the surface of the film and the lens, but such employment is seldom found as all of these sorts of effects may be obtained much more readily by the use of exterior mattes. An exterior matte is one, usually of larger size than an interior matte, placed in front of the lens at a distance which will give a diffused line of demarcation between the image photographed and that part which is closed off by the matte. When two mattes are used in conjunction in producing one picture, they are so employed that the diffused lines of demarcation between the different exposures fuse into one another and leave no betraying line to reveal exactly where the picture has been split. The amount of this diffusion is determined by two factors. The first factor is the distance from the matte to the lens and the second factor is the dia-

phragm opening, so that if double exposures are made under varying light conditions, the cameraman is confronted with a problem in which he has to equalize a number of different factors. If one exposure is taken in brighter light than the other he may place his second matte closer to the lens to obtain the same degree of diffusion with a smaller diaphragm or he may equalize his exposure by cutting down his shutter opening and place his matte at the same distance from the lens as his first in order to obtain the same degree of diffusion.

In using exterior mattes in place of matching each other exactly as is the case with interior mattes they must overlap one another slightly and the amount of this overlap is determined by the diaphragm opening. For a small diaphragm it is narrow, for a large one it is correspondingly wider. For cloud effects, he has a number of color filters of different hues and of different depths of color and, when using these, he generally, although not always, uses panchromatic negative stock which is sensitive not only to blue light, but to green, yellow and red to which ordinary film stock is comparatively insensitive. With ordinary negative stock only the most pronounced blonde will photograph as being light-haired. With panchromatic stock and a yellow screen he may make the yellow-haired heroine as blonde as he pleases and reduce freckles and facial imperfections to a minimum. With a graduated sky filter, he can give full exposure to objects in a scenic locality and yet retain the details of the beautiful clouds in the background, or bring out the blue distant mountains that would be scarcely visible were they photographed upon ordinary negative stock without a filter. With mattes of yellow celluloid the outer edges of the close-up may be diffused and darkened without suppressing them altogether, by means of mattes mechanically operated by a flexible shaft attached to an elongation of the shutter shaft or other moving part of the camera, one scene may be rolled aside and another take its place as it disappears; not by one dissolving into another, but as if one scene were slid on at one side and by its coming would push the other off at the other side, or, by changing from vertical to horizontal, make one picture go like the scene painted on a theater curtain which rolls up, disclosing the setting behind it.

Optical attachments of small reflecting prisms placed partially before the taking lens permit of double exposure effects being made at one exposure and so forth *ad infinitum*, limited only by the ingenuity and resources of the individual camera operator.

One attachment usually scorned by the average professional is the speedometer for giving the number of frames taken per second. While such an attachment is regarded by many as being superfluous, it should be of considerable value, especially to those operators who are engaged in the production of comedy films of the Mack Sennett type, for many comedy effects depend upon the accuracy with which certain number of pictures per second may be photographed, generally a number considerably less than sixteen per second, and while there are operators who can compete marvelously

with a stop watch in turning to a certain speed per second, they are the exception and not the rule.

Next in our line of attachments we come to the view finder, although we wish to register a protest against classifying the view finder as an attachment or accessory, as it is much too important to be otherwise than an integral part of the camera even if it seldom fulfills the functions for which it is provided. It is of the utmost importance that the view finder show plainly at all times the exact field covered by the lens of the camera and yet it can never do this exactly, because it is not possible to place the view finder so that it will have exactly the same point of view as the taking lens, unless by some as yet unknown device we can utilize the taking lens both as a finder and a photographic objective. The nearest approach to this ideal is perhaps found in the Bell and Howell camera where the lens performs both of these functions, but not simultaneously. This ideal condition being only fulfilled when the image can be viewed through the taking lens at the same time that the picture is being photographed. While this is theoretically not impossible, it is practically so on account of the amount of mechanism that it would be necessary to place in the space already occupied by the shutter to make such a device practical. We can, however, develop the view finder enough so that it is an instrument precise enough for our purposes by placing its objective lens as close as possible to that of the photographic objective and using a compensating device to account for the slight variation between the different view points of the two lenses. Another desirable feature with the view finder is that it should show the image brilliantly, right side up with the image right for right and left for left and not reversed as is usually the case. Negative lenses are not ideal for this purpose as they depend for their accuracy upon the position of the eye being along a certain axis. A view finder should be within the camera box, so that it does not have to be adjusted to the camera after it is taken from the case. It should be plainly and easily visible to the photographer's eye from his natural cranking position. Mr. Akeley, in designing his camera, has paid more attention to the important functions of the view finder than any other camera manufacturer, and yet all must admit that the ideal view finder is yet to be made. Discussion of the problem of an ideal view finder brings us to the problem of the range finder, and by range finder we mean an instrument which performs for the camera exactly the same function that the range finder performs for the artillery—that of measuring the distance from the camera to the object so that the focus may be instantly set without measuring the distance or focusing upon the film or ground glass. Range finders are so well and scientifically worked out that it should be no considerable problem at all to make a simple form of this instrument which would fulfill all of the requirements for cinematographic use. Such an instrument is an integral part of some models of pocket cameras manufactured by the Eastman Company and the manufacturers of moving picture cameras should not lag in following this example. View and range finders are, of course, great aides to the accomplishment of the most efficient use of the photographic objective.

The taking lens is, of course, the most important part of the camera. It must be of the best quality possible, suitably mounted so that it can be accurately focused upon the plane of the film, some modification of the micrometer principle being probably the best and most accurate practical method. Once the scale of distances are calibrated upon a micrometer scale, so that no climatic condition or ordinary wear and tear will derange its adjustment, there should be no further use for focusing devices except to occasionally check results in order to see that no possible accident has happened to its mechanism. Where an accurate calibration of the focusing scale has been made under favorable conditions with a reliable focusing mount, it would be impossible to make any better adjustment by focusing on the thing itself than to measure the distance and set the scale to the proper calibration, no matter how often it may be necessary to inspect the image in the framing aperture for the purposes of lining up or obtaining composition. In an instrument where such accurate work is required as in a motion picture camera, a ground glass for focusing purpose is an absurdity, the coarseness of its surface is much greater than the limit of definition to which it is desirable to adjust the lens. Ground glass should only be used for the determination of the extent of the image within the frame. For focusing the objective a microscope should be provided, so adjusted that its cross hairs or reticule lines will appear in the focal plans; by means of such a microscope the focusing mount should be calibrated. For purposes of viewing the image in the framing aperture some form of reflex attachment is of considerable value. If the mechanism of the camera gives room for the placing of such an attachment between the lens and the film, so much the better, as it renders the opening of the camera and the spoiling of film unnecessary.

As the subject of focusing devices alone is worthy of an extensive paper, it would be unwise for us to dilate here upon the various phases of this subject.

Under the head of attachments, we had also placed in our notes metal fittings. This seems almost superfluous, as there can be no doubt that the film race ways should be made of hard metal capable of receiving and retaining a mirror-like polish upon which there could be no chance of the film being scratched or abraided. Frictional contact with the film should be avoided wherever possible. Static electricity is one of the greatest enemies of the motion picture photographer and friction upon celluloid, as everyone knows, generates static electricity. Here again we must cut our dissertation short as the cause of static, static markings, and static prevention are the subjects for another exhaustive paper, and we dare not intrude this subject upon an already lengthy article. The subject of camera attachments is necessarily a lengthy one and we have attempted in this paper to touch upon only the more salient features in the hope that we may furnish the germ of an idea which may develop in the brain of some of our more able confrères and give to the cinematographic world some noteworthy addition to its many inventions.